OpenSees Workshop

Online Tutoring Course

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Educational Background:

2004-2008 BSc, Civil Engineering, KNT University
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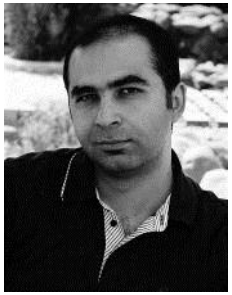

Hadi Kenarangi,
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2003-2007 BSc, Civil Engineering, Tabriz University
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2013 PhD, Structural and Earthquake Eng., SUNY at Buffalo


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MORE
Write Post
Add Photo / Video
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Add File
Write something...
Hadi Kenarangi
Sharif University OpenSees Student Group searches for talented volunteers who can contribute in developing new commands, examples, writing tutoring hand outs, developing SOC (SAP2000 to OpenSees Converter developed by this group).
Volunteers are expected to be experienced in OpenSees, MATLAB and Programming Languages. Knowledge in Microsoft Visual Studio will be an advantage.
Please send your CV to Mr. Seyed Mojtaba Hosseini (hosseinigelekolai@gmail.com) or Hadi Kenarangi (hadi.kenarangi@gmail.com).
Thanks
Sharif University of Technology
OpenSees
Student Group
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+ Add People to Group
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Add Friend
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10 mutual friends
Add Friend
Hamidreza Alinezhad
9 mutual friends
Add Friend
Maryami Rezazadeh
1 mutual friend
Add Friend
Bahman Farahmand Azar
3 mutual friends
Add Friend
Sevil Marzban
Add Friend

SUT OpenSees Group

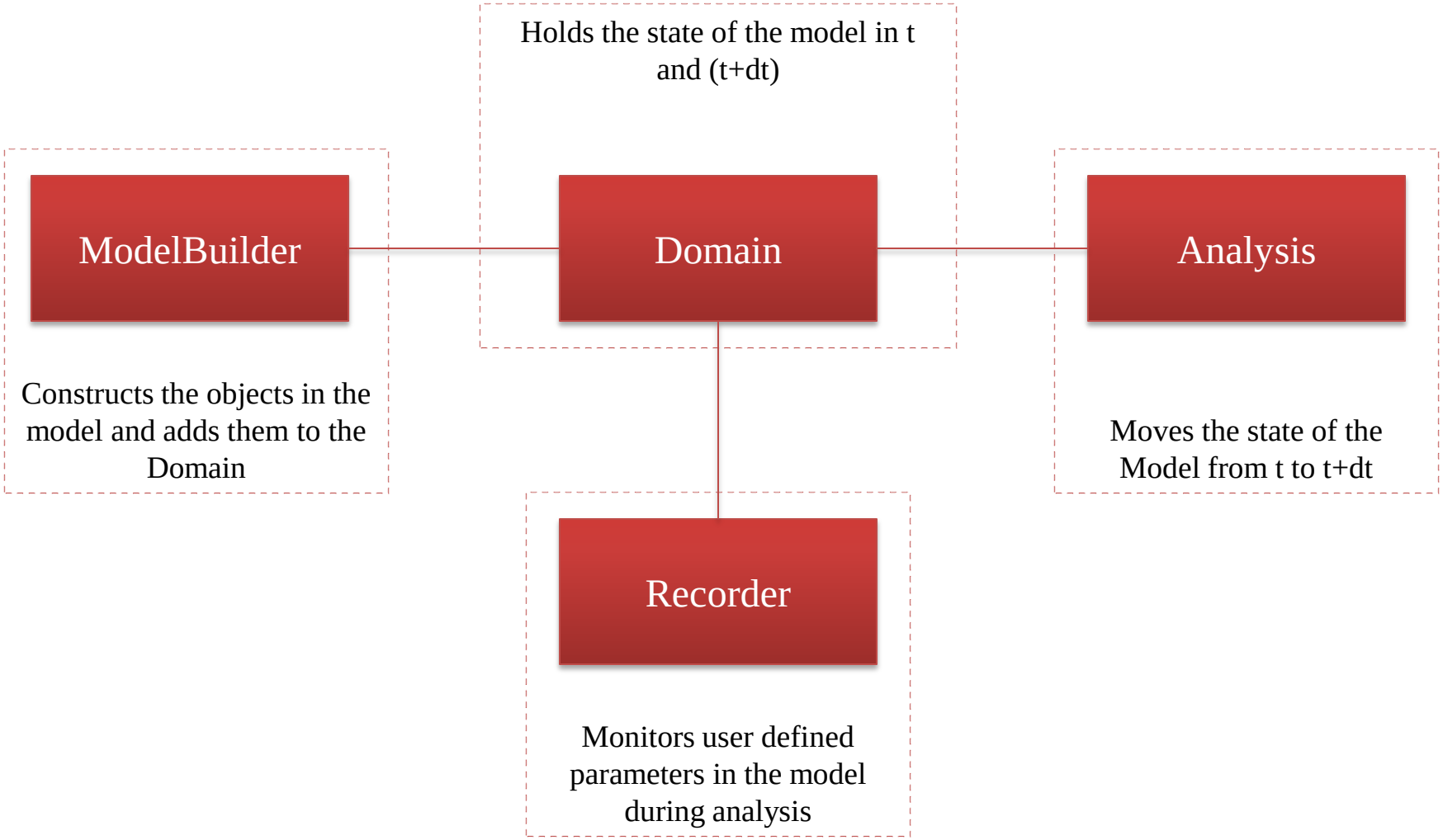
Some of Past works (Since 2007):

- OpenSees Book: coming soon
- OpenSees Tutoring Courses in:
  - Sharif University of Technology, Tehran, Iran.
  - Khajeh Nasir University of Technology, Tehran, Iran.
  - Civil House Engineering Institute, Tehran, Iran.
  - Noshirvani University of Technology, Babol, Iran.
  - 9th International Congress on Civil Engineering, 2012 May 8-10, Isfahan University Of Technology, Isfahan, Iran.
- Development of Related Softwares:
  - SAP2000 to OpenSees Convertor (SOC2D), A code developed in MatLab which easily converts SAP2000 models into OpenSees.
  - SOC3D
- Academic and Professional Projects:
  - Modeling various structural models and simulations such as:
    - Bridges, Steel and RC Buildings, Spatial Structures, Passive and Active Control, Masonry Infill Walls, SMA, Wind Turbine, etc.

What is OpenSees?

- A software framework for simulation applications in earthquake engineering using finite element methods. OpenSees is not a code.
- As open-source software, it has the potential for a community code for earthquake engineering.
- OpenSees has been under development by PEER since before 1997.
- Large group of developers and user.
- NEESgrid and NEESit support integration and extension since 2003.
- Open-source and royalty free license for noncommercial use.

OpenSees Framework



OpenSees

- ModelBuilder Object is responsible for building the objects in the model and adding them to the domain.
- Recorder Object monitors user-specified objects of the model during the analysis.
- Analysis Object is responsible for performing the analysis.
- Domain Object is responsible for storing the objects created by the ModelBuilder object and for providing the Analysis and Recorder objects access to these objects.

Model-Building Objects

- model Command
- node Command
- mass Command
- Constraints Objects
- uniaxialMaterial Command
- nDMaterial Command
- section Command
- element Command
- block Command
- region Command
- Geometric Transformation Command
- Time Series
- pattern Command

Recorder Objects

- Node Recorder
- EnvelopeNode Recorder
- MaxNodeDisp Recorder
- Drift Recorder
- Element Recorder
- EnvelopeElement Recorder
- Display Recorder
- Plot Recorder
- Playback Command

Analysis Objects

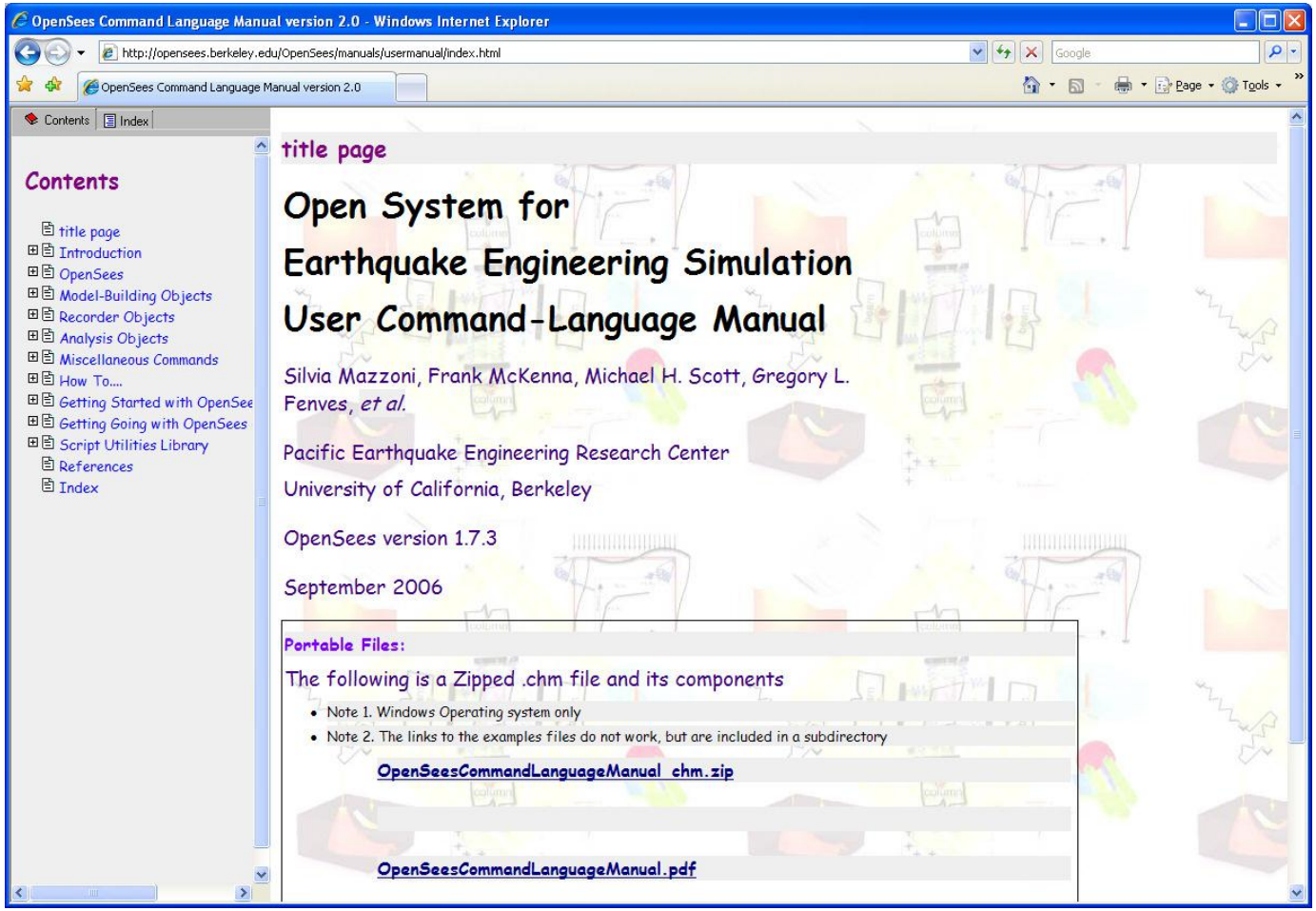
- constraints Command
- numberer Command
- analysis Command
- algorithm Command
- integrator Command
- system Command
- test Command
- analyze Command
- rayleigh Command
- eigen Command
- dataBase Commands

OpenSees User Manual

A document providing the syntax and description of OpenSees commands in 3 formats:

- HTML Manual – on-line HTML document, residing on OpenSees server. Always going to be the most current.
- MS Word – downloadable and printable Word document in PDF format.
- Offline Windows – downloadable .chm file. it is similar to the HTML format, but the file resides on your computer.

1. HTML On-line Format



2. MS Word Format - PDF

Open System for Earthquake Engineering Simulation (OpenSees)

OpenSees Command Language Manual

Silvia Mazzoni, Frank McKenna, Michael H. Scott, Gregory L. Fenves, et al.

Elastic Beam Column Element

This command is used to construct an elasticBeamColumn element object. The arguments for the construction of an elastic beam-column element depend on the dimension of the problem, *ndm* (page 29):

For a two-dimensional problem:

```
element elasticBeamColumn $eleTag $iNode $jNode $A $E $Iz $transfTag
```

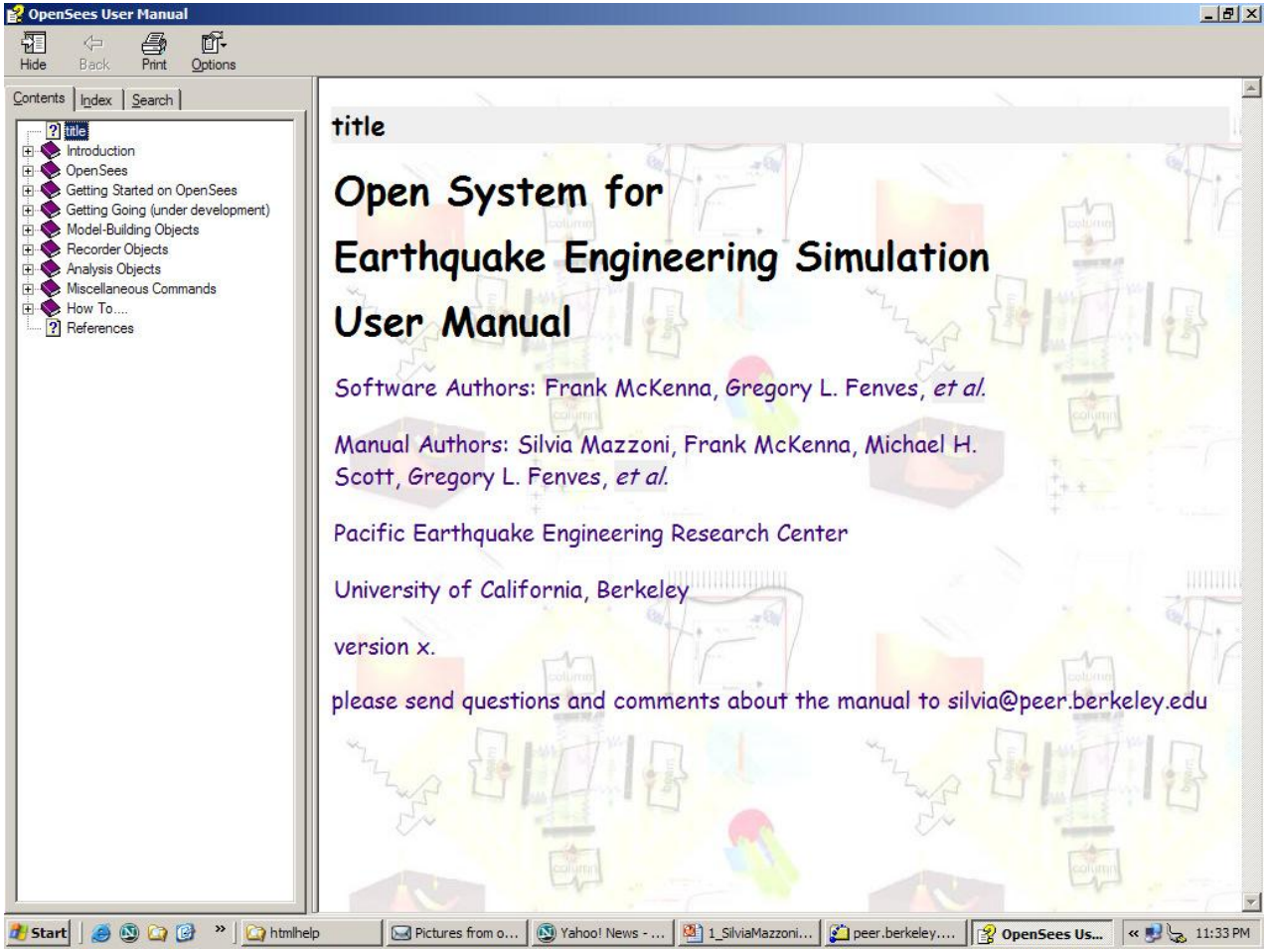
For a three-dimensional problem:

```
element elasticBeamColumn $eleTag $iNode $jNode $A $E $G $J $Iy $Iz
        $transfTag
```

$eleTag		unique element object tag
$iNode	$jNode	end nodes
$A		cross-sectional area of element
$E		Young's Modulus
$G		Shear Modulus
$J		torsional moment of inertia of cross section
$Iz		second moment of area about the local z-axis
$Iy		second moment of area about the local y-axis
$transfTag		identifier for previously-defined *coordinate-transformation* (page 280) (CrdTransf) object

The valid queries to an elastic beam-column element when creating an *ElementRecorder* (page 307) object are 'stiffness' and 'force.'

3 .chm file for MS Windows



4 .Quick Reference Guide-PDF

The OpenSees Quick Reference Guide
Opensees Student Group, May 8, 2012

Seyed Mojtaba Hosseini Gelekolai and Hadi Kenarangi
Sharif University of Technology, Tehran, Iran

1-Modeling Commands

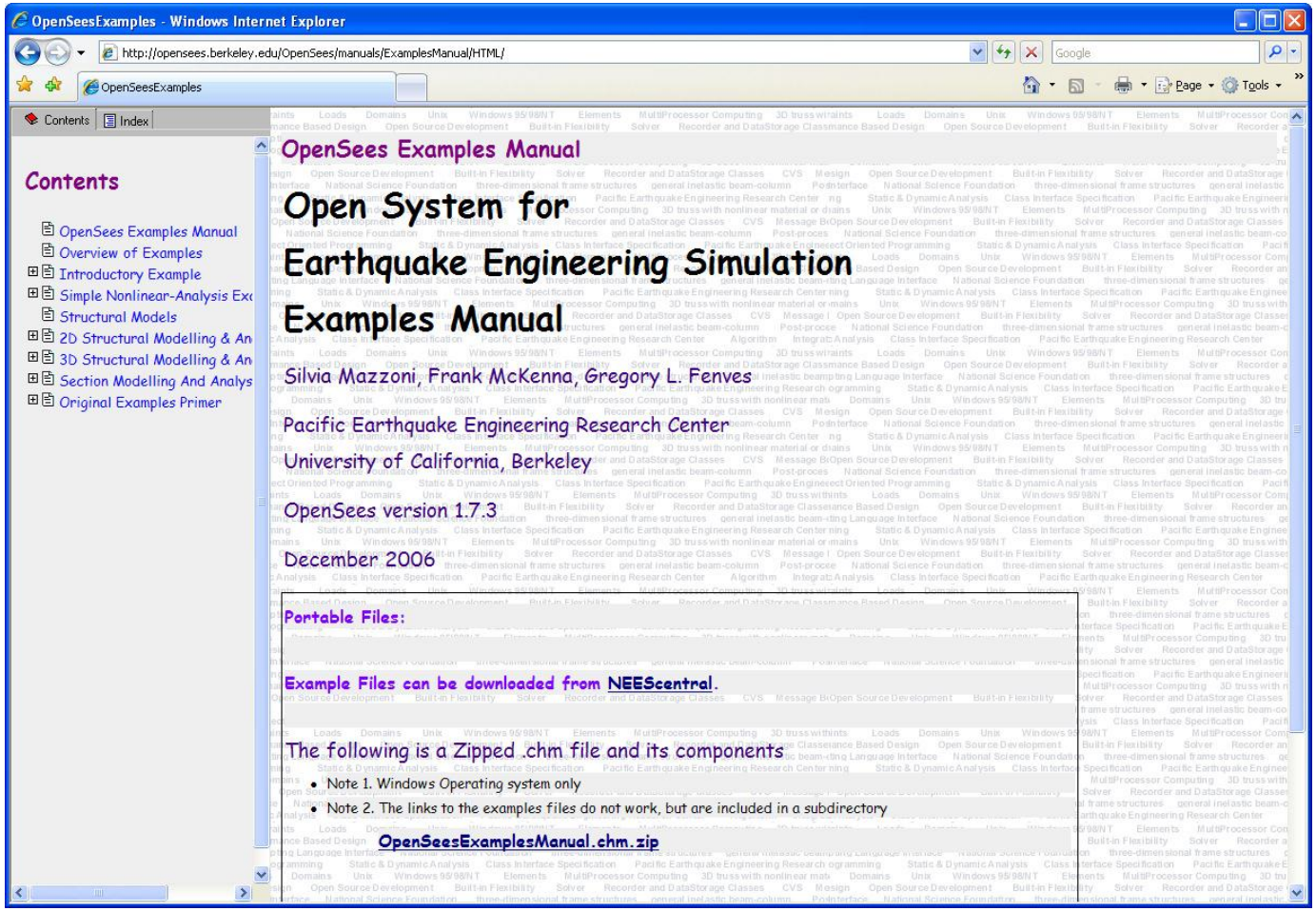
model modelBuilderType <specific model builder args>
model BasicBuilder -ndm ndm? <-ndf ndf?>

node nodeTag? (ndm coordinates?) <-mass (ndf values?)>

mass nodeTag? (ndf values?)

uniaxialMaterial materialType <specific material args>
uniaxialMaterial Elastic matTag? E? <eta?>
uniaxialMaterial ElasticPP matTag? E? ep?
uniaxialMaterial ElasticPPGap matTag? E? fy? gap?
uniaxialMaterial Parallel matTag? tag1? tag2? ... <-min min?> <-max max?>
uniaxialMaterial Series matTag? tag1? tag2? ...
uniaxialMaterial Hardening matTag? E? sigmaY? H_iso? H_kin?
uniaxialMaterial Steel01 matTag? fy? E0? b? <a1? a2? a3? a4?> <-min min?> <-max max?>
uniaxialMaterial Concrete01 matTag? fpc? epsc0? fpcu? epscu? <-min min?> <-max max?>
uniaxialMaterial Hysteretic matTag? s1p? e1p? s2p? e2p? <s3p? e3p?> s1n? e1n? s2n? e2n?
<s3n? e3n?> pinchX? pinchY? damage1? damage2? <beta?>

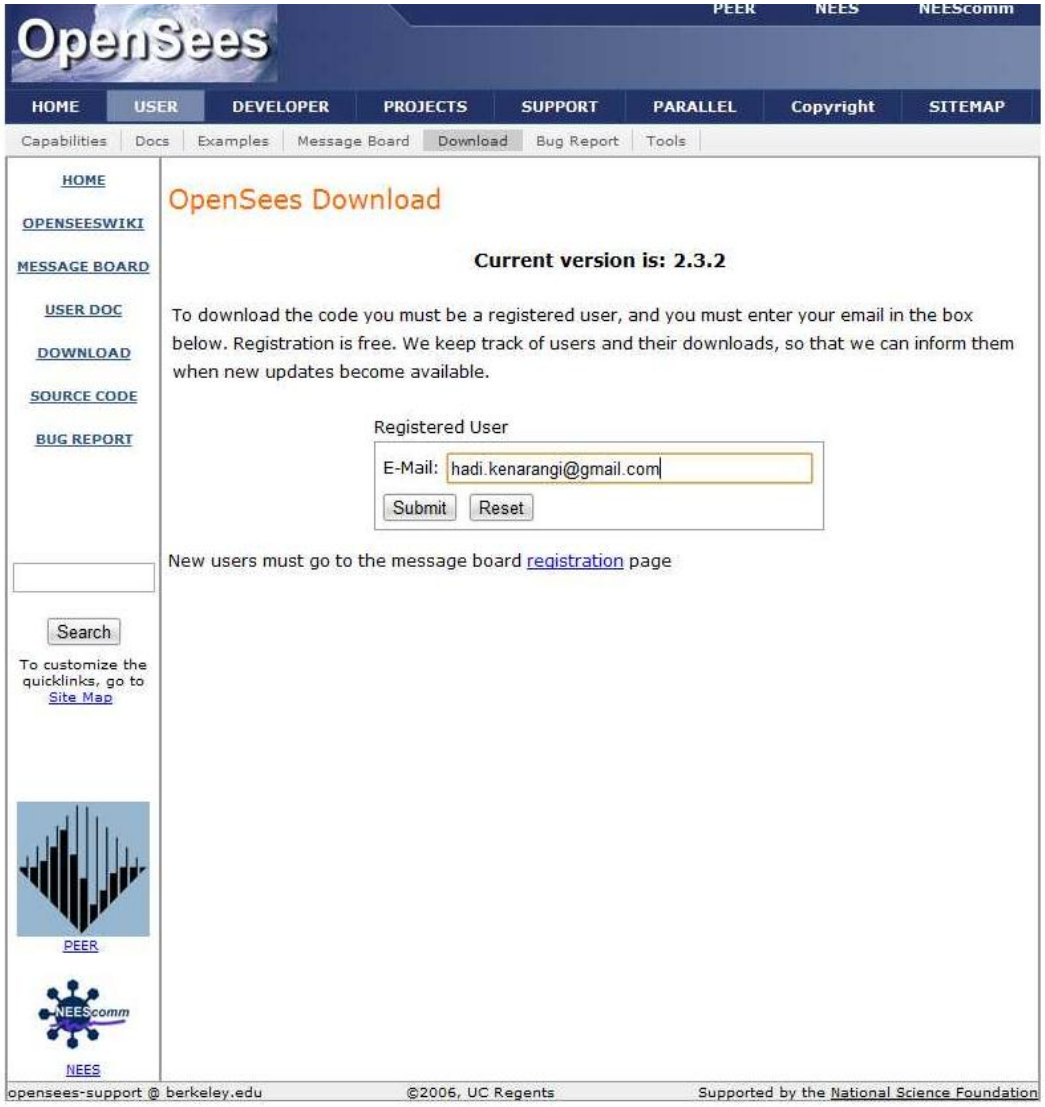
5 . OpenSees Examples Manual-chm



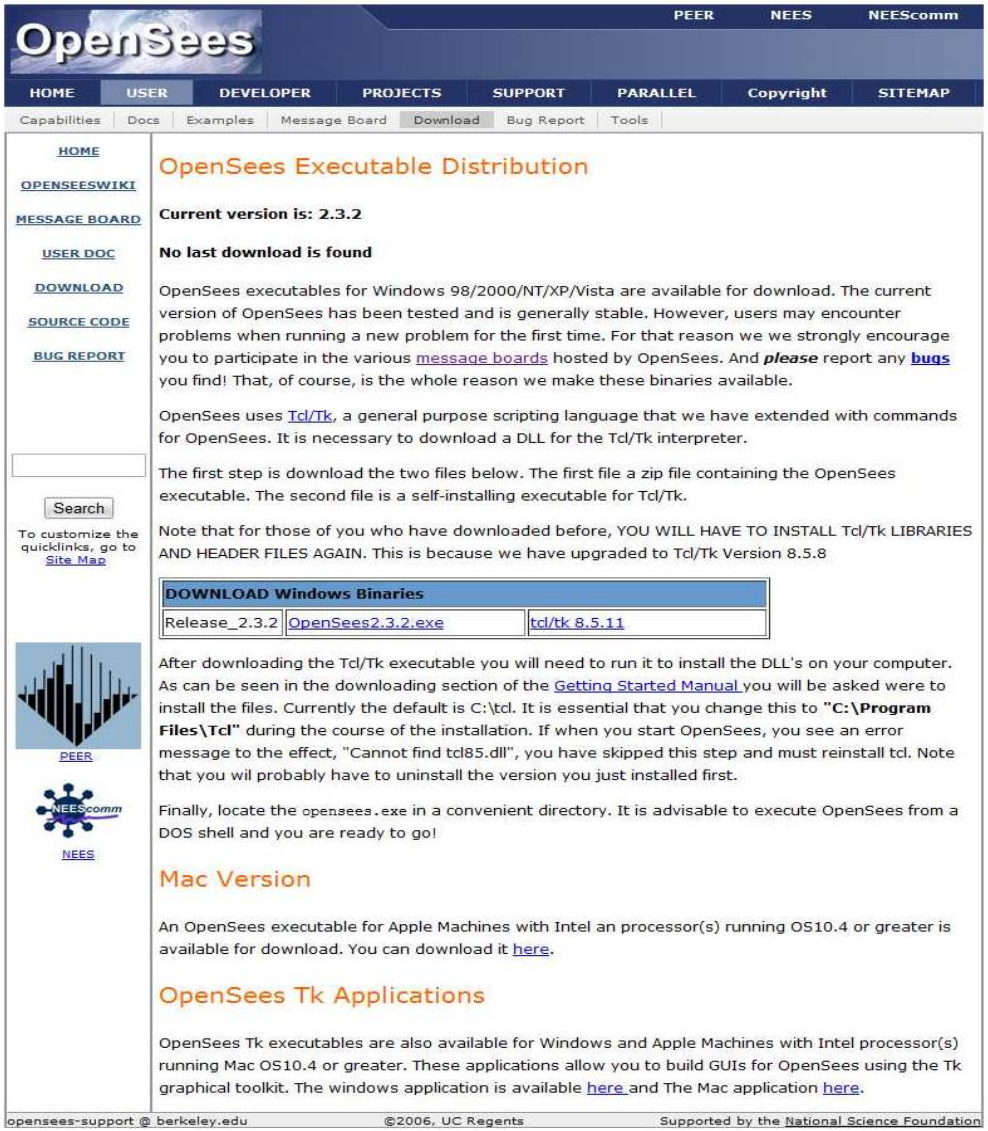
How to Download OpenSees

http://opensees.berkeley.edu

Your Email Address



Now Download



OpenSees

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OpenSees Executable Distribution

Current version is: 2.3.2

No last download is found

OpenSees executables for Windows 98/2000/NT/XP/Vista are available for download. The current version of OpenSees has been tested and is generally stable. However, users may encounter problems when running a new problem for the first time. For that reason we we strongly encourage you to participate in the various message boards hosted by OpenSees. And ***please*** report any **bugs** you find! That, of course, is the whole reason we make these binaries available.

OpenSees uses Tcl/Tk, a general purpose scripting language that we have extended with commands for OpenSees. It is necessary to download a DLL for the Tcl/Tk interpreter.

The first step is download the two files below. The first file a zip file containing the OpenSees executable. The second file is a self-installing executable for Tcl/Tk.

Note that for those of you who have downloaded before, YOU WILL HAVE TO INSTALL Tcl/Tk LIBRARIES AND HEADER FILES AGAIN. This is because we have upgraded to Tcl/Tk Version 8.5.8

DOWNLOAD Windows Binaries		
Release_2.3.2	OpenSees2.3.2.exe	tcl/tk 8.5.11

After downloading the Tcl/Tk executable you will need to run it to install the DLL's on your computer. As can be seen in the downloading section of the Getting Started Manual you will be asked were to install the files. Currently the default is C:\tcl. It is essential that you change this to **"C:\Program Files\Tcl"** during the course of the installation. If when you start OpenSees, you see an error message to the effect, "Cannot find tcl85.dll", you have skipped this step and must reinstall tcl. Note that you wil probably have to uninstall the version you just installed first.

Finally, locate the `opensees.exe` in a convenient directory. It is advisable to execute OpenSees from a DOS shell and you are ready to go!

Mac Version

An OpenSees executable for Apple Machines with Intel an processor(s) running OS10.4 or greater is available for download. You can download it here.

OpenSees Tk Applications

OpenSees Tk executables are also available for Windows and Apple Machines with Intel processor(s) running Mac OS10.4 or greater. These applications allow you to build GUIs for OpenSees using the Tk graphical toolkit. The windows application is available here and The Mac application here.

opensees-support @ berkeley.edu ©2006, UC Regents Supported by the National Science Foundation

OpenSees: Open Source

Resources for Developers

Welcome! This page contains some useful information for you brave souls who wish to get involved in the code development of OpenSees.

Documentation

Before you begin and for when you get stuck there is always the documentation. For new users to OpenSees, have a look at the primers to get yourselves more familiar with the overall design. For you programmers who need to understand the inner workings of the classes have a look at the Class Specifications.

Browse the Source Code

Browse the up-to-the-minute latest version of the source code online.

Download

Download the source via FTP from our server. Details are on the Download page. Source drops to the FTP server usually occur monthly!!.

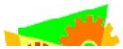
CVS

Those doing active development can check out the latest source using CVS. This is the preferred method, as it lets you get up-to-the-minute changes and merge them with your own. Details are on our CVS page.

Builds

Look at the build instructions to find out how to compile this beast on your platform. If you are working on a new platform and get the beast to run,

Contribute



To contribute code, submit your changes to following the instructions. If the code changes are approved they'll be committed.

OpenSees Community Forum

Seven Forum Categories

Forum	Topics	Posts	Last Post
OpenSees			
OpenSees.exe Users Forum for OpenSees users to post questions, comments, etc. on the use of the OpenSees interpreter, OpenSees.exe Moderator silvia	1873	6750	Mon Aug 25, 2008 10:14 am TWI
Soil Modelling A forum dedicated to users with questions regarding soil materials and elements.	16	44	Mon Jul 21, 2008 7:41 pm rjaeger
Framework For developers writing C++, Fortran, Java, code who have questions or comments to make. Moderator silvia	233	829	Fri Aug 15, 2008 11:42 pm neallee
Parallel Processing This forum is for issues related to parallel processing and OpenSees using the new interpreters OpenSeesSP and OpenSeesMP	14	33	Wed Jul 23, 2008 10:11 pm hongqi
Useful Scripts. If you have a script you think might be useful to others post it here. Hopefully we will be able to get the most useful of these incorporated in the manuals. Moderator silvia	27	78	Tue Aug 12, 2008 12:15 am khili83
Documentation For posts concerning the documentation, errors, ommissions, general comments, etc. Moderator silvia	127	352	Mon Aug 04, 2008 8:22 am pennycorp66
Future Directions A forum dedicated to the future direction of OpenSees, i.e. what would you like, what do you need. Moderator silvia	29	104	Mon Aug 18, 2008 1:18 am Andrew

Very Busy Message Board

OpenSees.exe Users

Moderator: silvia

Users browsing this forum: silvia

Goto page 1, 2, 3 ... 36, 37, 38 Next

newtopic The OpenSees Community Forum Index -> OpenSees.exe Users

Mark all topics read

Topics	Replies	Author	Views	Last Post
Sticky: First Public Release of BuildingTcl	7	silvia	466	Fri Aug 22, 2008 5:51 am hresquivelo
Sticky: OpenSees Days 2008, 8-9 September. Registration open	4	silvia	433	Thu Aug 14, 2008 2:40 pm silvia
Is consecutive multiple analysis possible in OpenSees?	8	TWI	130	Mon Aug 25, 2008 10:14 am TWI
axial load in pushover analysis and IDA method	1	sheng0122	55	Mon Aug 25, 2008 9:46 am esi_opensees
how to move the load pattern?	5	zhmkitten	60	Mon Aug 25, 2008 8:03 am zhmkitten
dynamic analysis of rocking frame	1	ca493	20	Mon Aug 25, 2008 6:35 am silvia
fracture modeling	7	ca493	160	Sun Aug 24, 2008 5:57 pm ca493
Sorry...	4	jk295	136	Sun Aug 24, 2008 10:29 am silvia
eigenvalue analysis error	2	mrathore	55	Fri Aug 22, 2008 4:08 pm Prayag Sayani
using scale factor	6	jk295	74	Fri Aug 22, 2008 12:48 pm jk295
Model of tallbuilding in opensees	1	dinochen1983	45	Fri Aug 22, 2008 10:42 am silvia
nonlinear static analysis	1	susan	28	Fri Aug 22, 2008 10:38 am silvia

Our OpenSees Facebook Group

OpenSees.exe

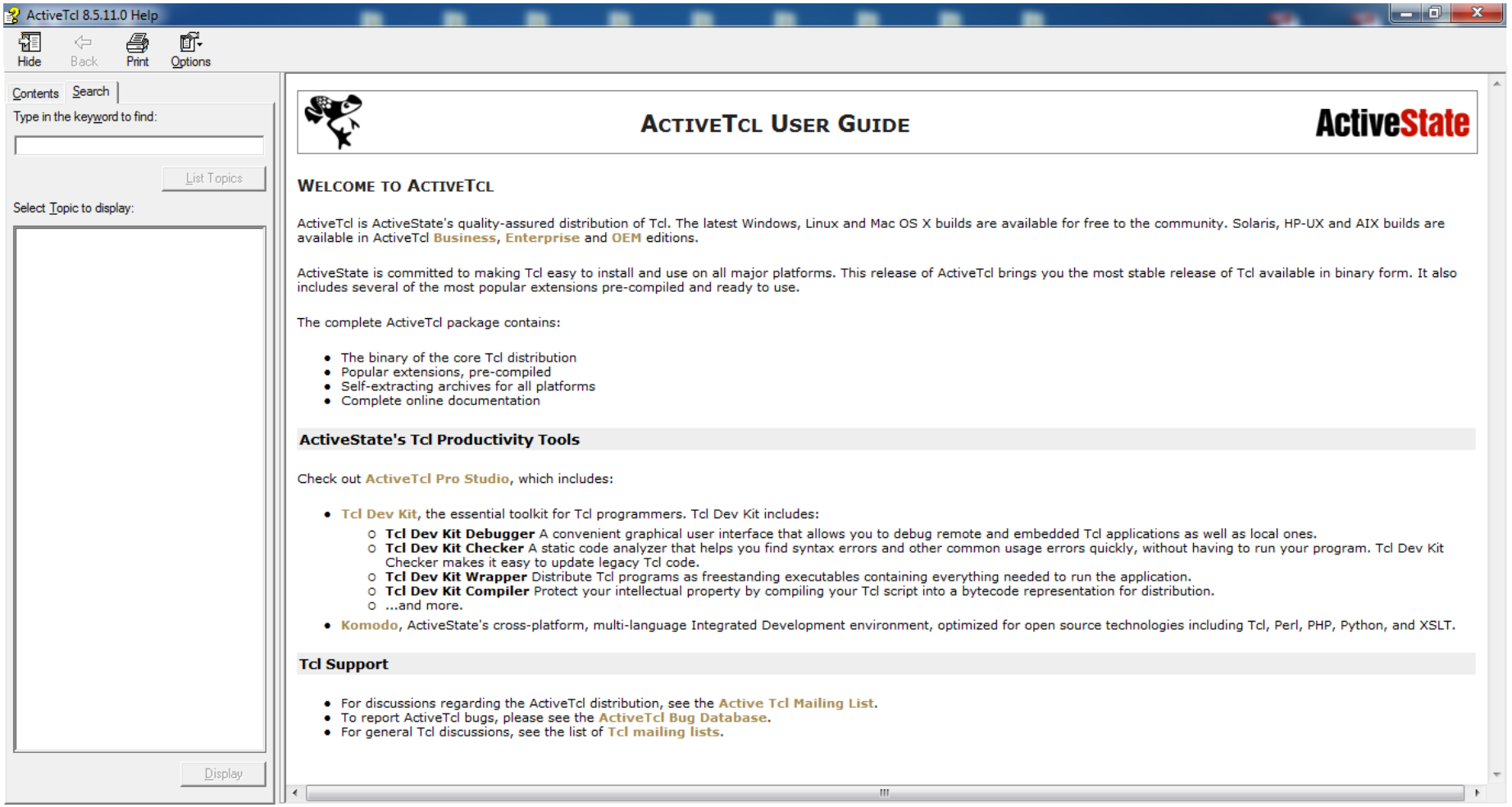
- OpenSees is an Open-Source Software Framework for developing Nonlinear Finite Element Applications for both sequential and parallel environments.

- OpenSees.exe is an extension of the Tcl interpreter for finite element analysis which uses this framework. It is an example of an application that can be developed using the framework.

What is Tcl

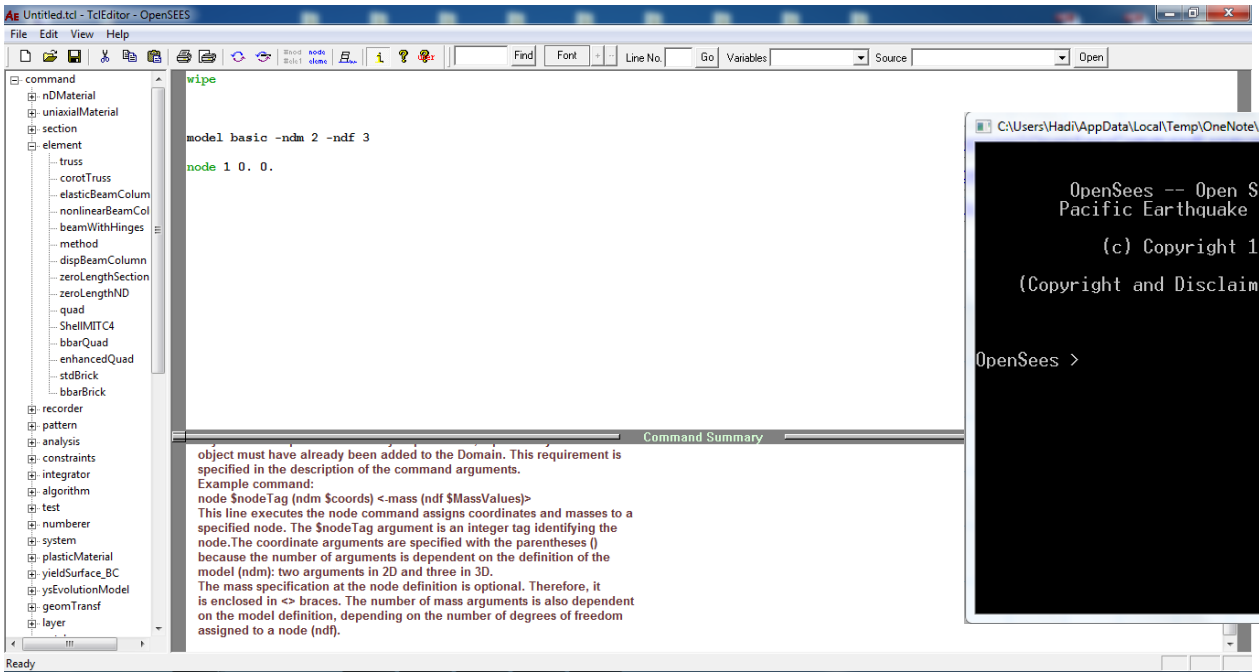
- Tcl is a string-based scripting language.
- Variables and variable substitution
- Expression evaluation
- Basic control structures (if , while, for, foreach)
- Procedures
- File manipulation
- Sourcing other files

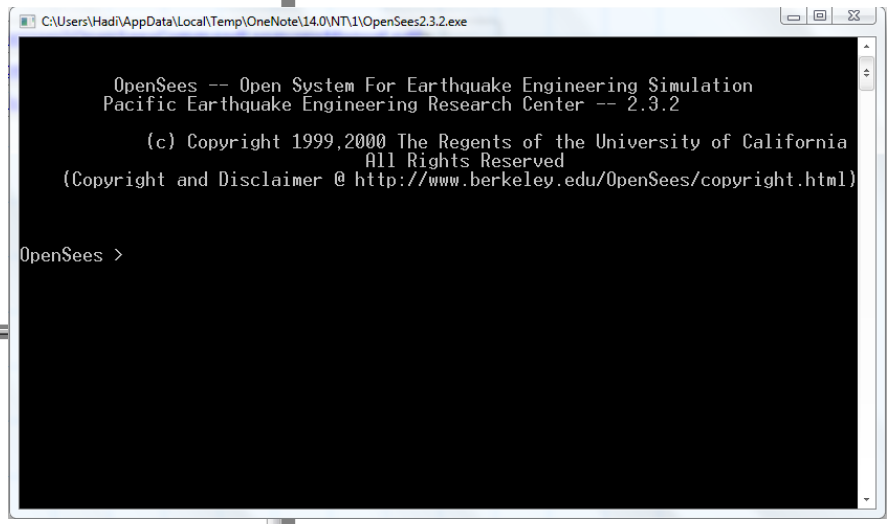
TCL Help


ActiveTcl 8.5.11.0 Help
Hide
Back
Print
Options
Contents
Search
Type in the keyword to find:
List Topics
Select Topic to display:
Display
ACTIVETCL USER GUIDE
ActiveState
WELCOME TO ACTIVETCL
ActiveTcl is ActiveState's quality-assured distribution of Tcl. The latest Windows, Linux and Mac OS X builds are available for free to the community. Solaris, HP-UX and AIX builds are available in ActiveTcl Business, Enterprise and OEM editions.
ActiveState is committed to making Tcl easy to install and use on all major platforms. This release of ActiveTcl brings you the most stable release of Tcl available in binary form. It also includes several of the most popular extensions pre-compiled and ready to use.
The complete ActiveTcl package contains:
The binary of the core Tcl distribution
Popular extensions, pre-compiled
Self-extracting archives for all platforms
Complete online documentation
ActiveState's Tcl Productivity Tools
Check out ActiveTcl Pro Studio, which includes:
Tcl Dev Kit, the essential toolkit for Tcl programmers. Tcl Dev Kit includes:
Tcl Dev Kit Debugger A convenient graphical user interface that allows you to debug remote and embedded Tcl applications as well as local ones.
Tcl Dev Kit Checker A static code analyzer that helps you find syntax errors and other common usage errors quickly, without having to run your program. Tcl Dev Kit Checker makes it easy to update legacy Tcl code.
Tcl Dev Kit Wrapper Distribute Tcl programs as freestanding executables containing everything needed to run the application.
Tcl Dev Kit Compiler Protect your intellectual property by compiling your Tcl script into a bytecode representation for distribution.
...and more.
Komodo, ActiveState's cross-platform, multi-language Integrated Development environment, optimized for open source technologies including Tcl, Perl, PHP, Python, and XSLT.
Tcl Support
For discussions regarding the ActiveTcl distribution, see the Active Tcl Mailing List.
To report ActiveTcl bugs, please see the ActiveTcl Bug Database.
For general Tcl discussions, see the list of Tcl mailing lists.

How to Install

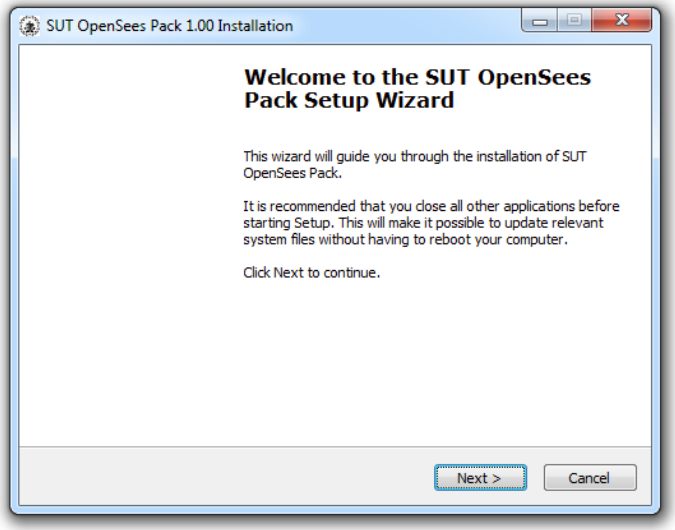
- Install ActiveTcl8.4.6.1 and ActiveTcl8.5.11 on drive C:\
- Install Install_OSP.exe on drive C:\
- Copy tcleditor folder to C:\
- Go to C:\tcleditor\bin right click on TclEditor.exe select send shortcut to desktop
- Now you can easily use OpenSees by double clicking tcleditor on your desktop





How to Install

Welcome to SUT OpenSees Pack Installer



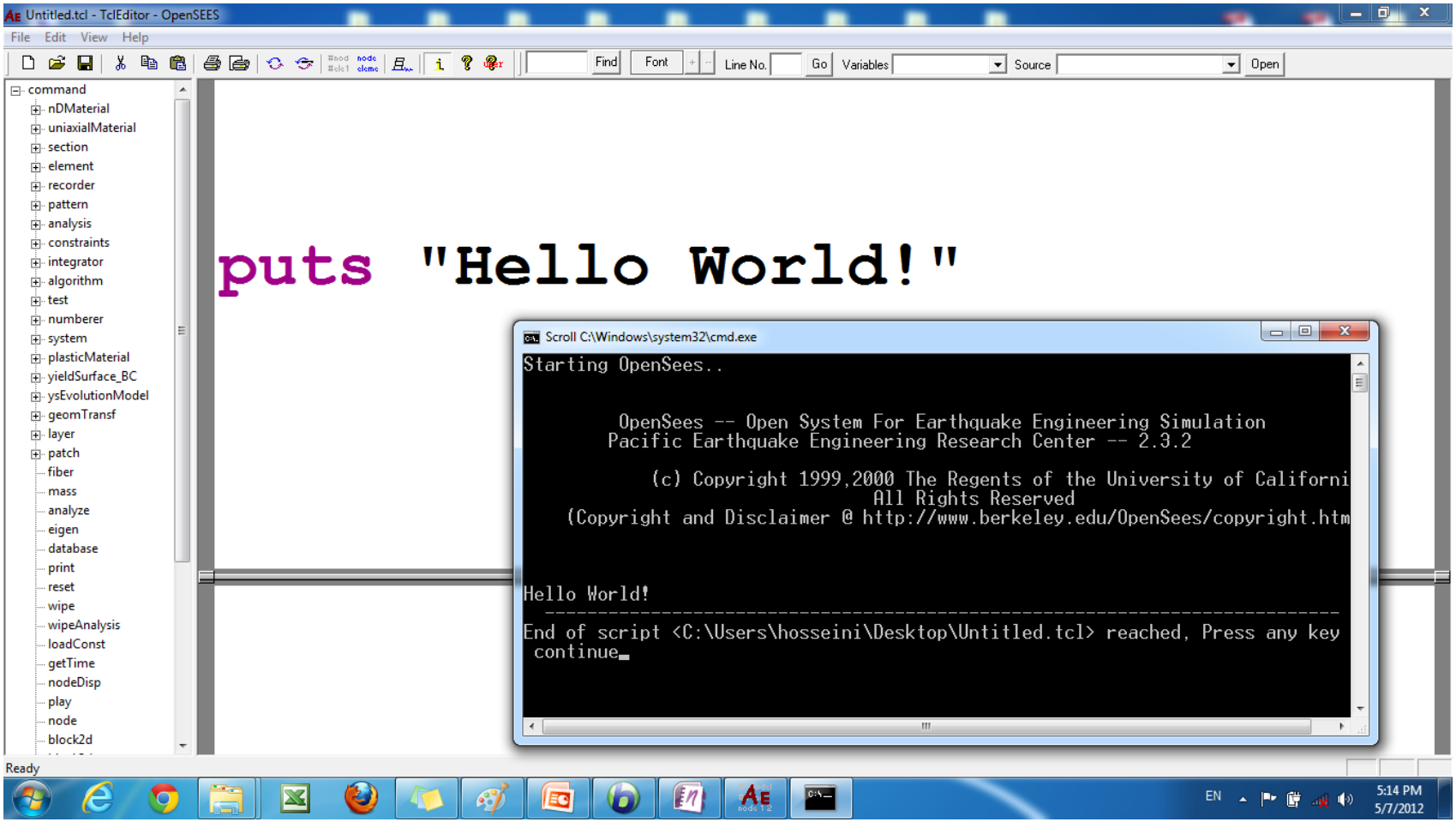
Sharif University of Technology

OpenSees

Student Group

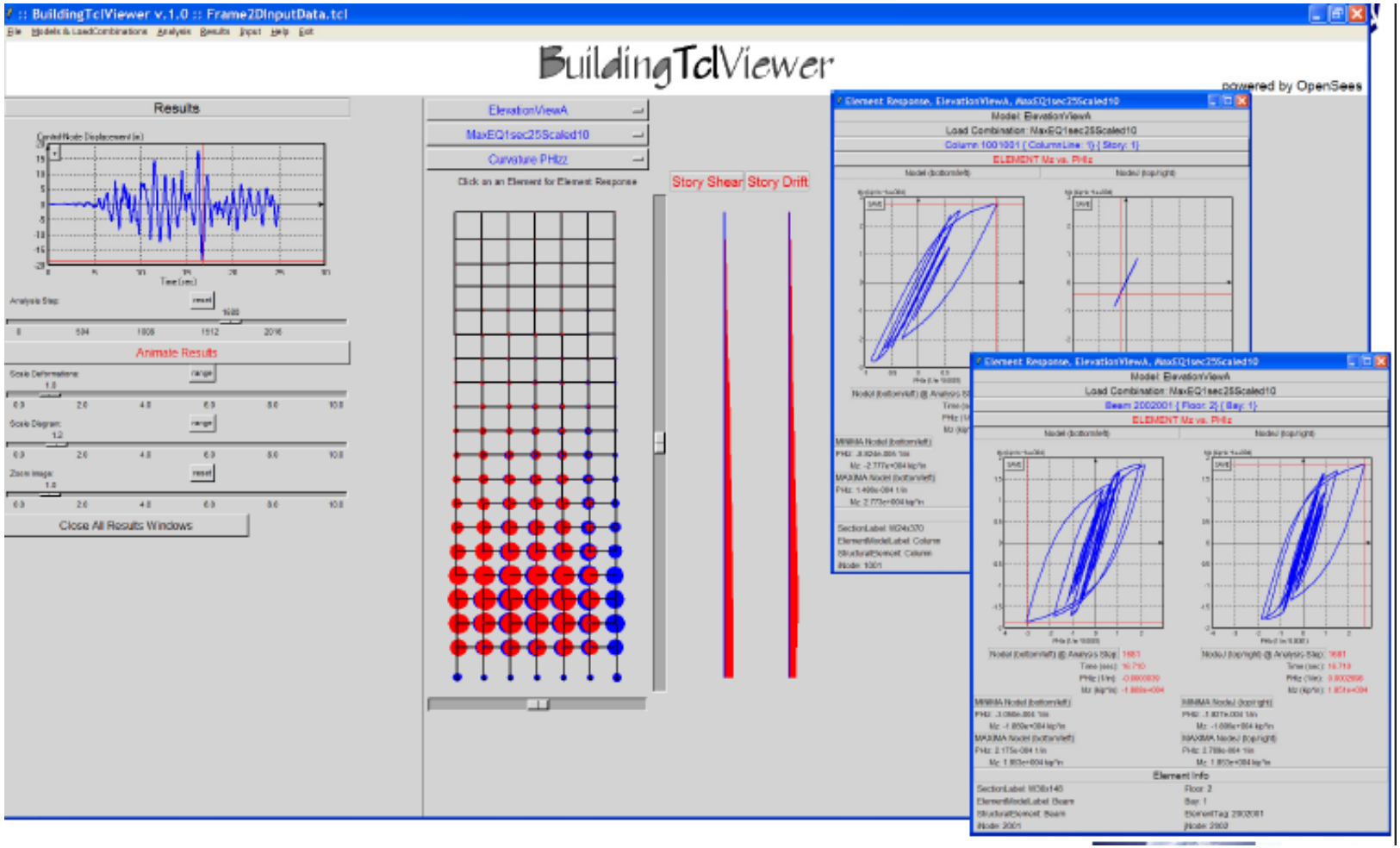
by: Hadi Kenarangi hadi_kenarangi@alum.sharif.edu
Seyed Mojtaba Hosseini Gelekolai hosseinigelekolai@gmail.com

Hello World! (My First Code)

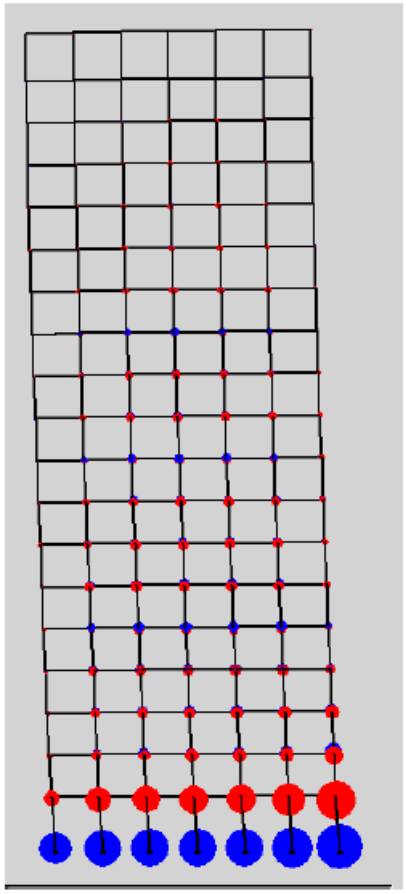


GUIs are possible

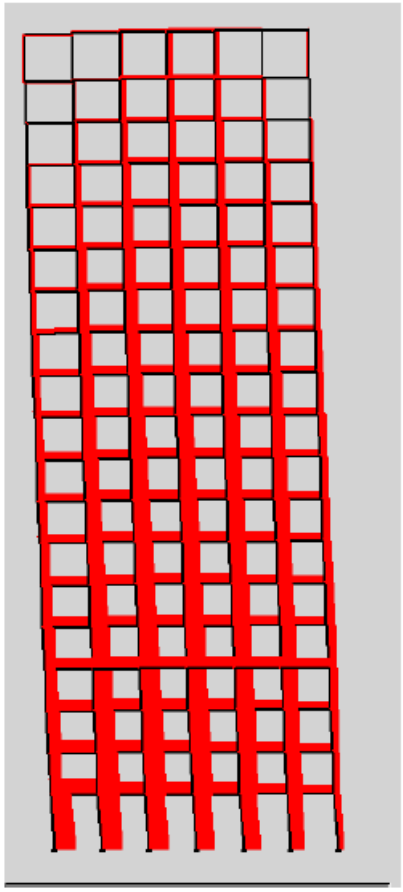
1. BuildingTcl



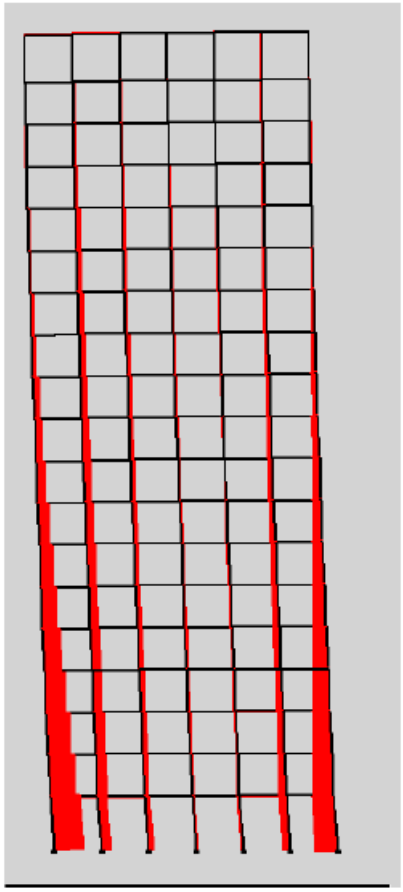
BuildingTclViewer: Results - RC Frame



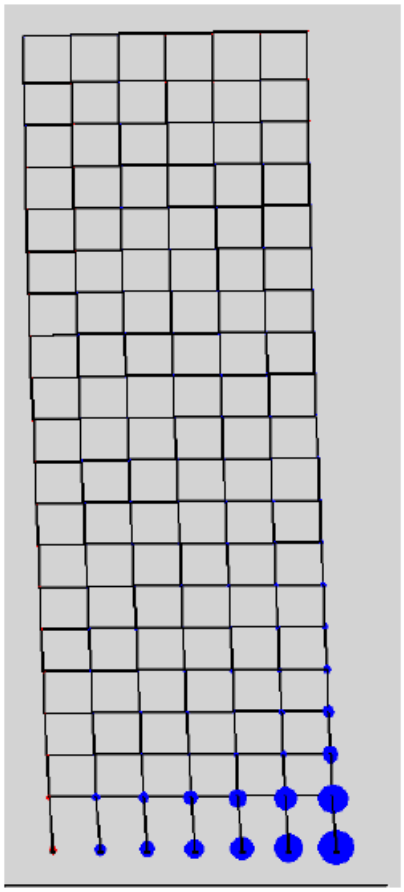
Curvature



Shear Force



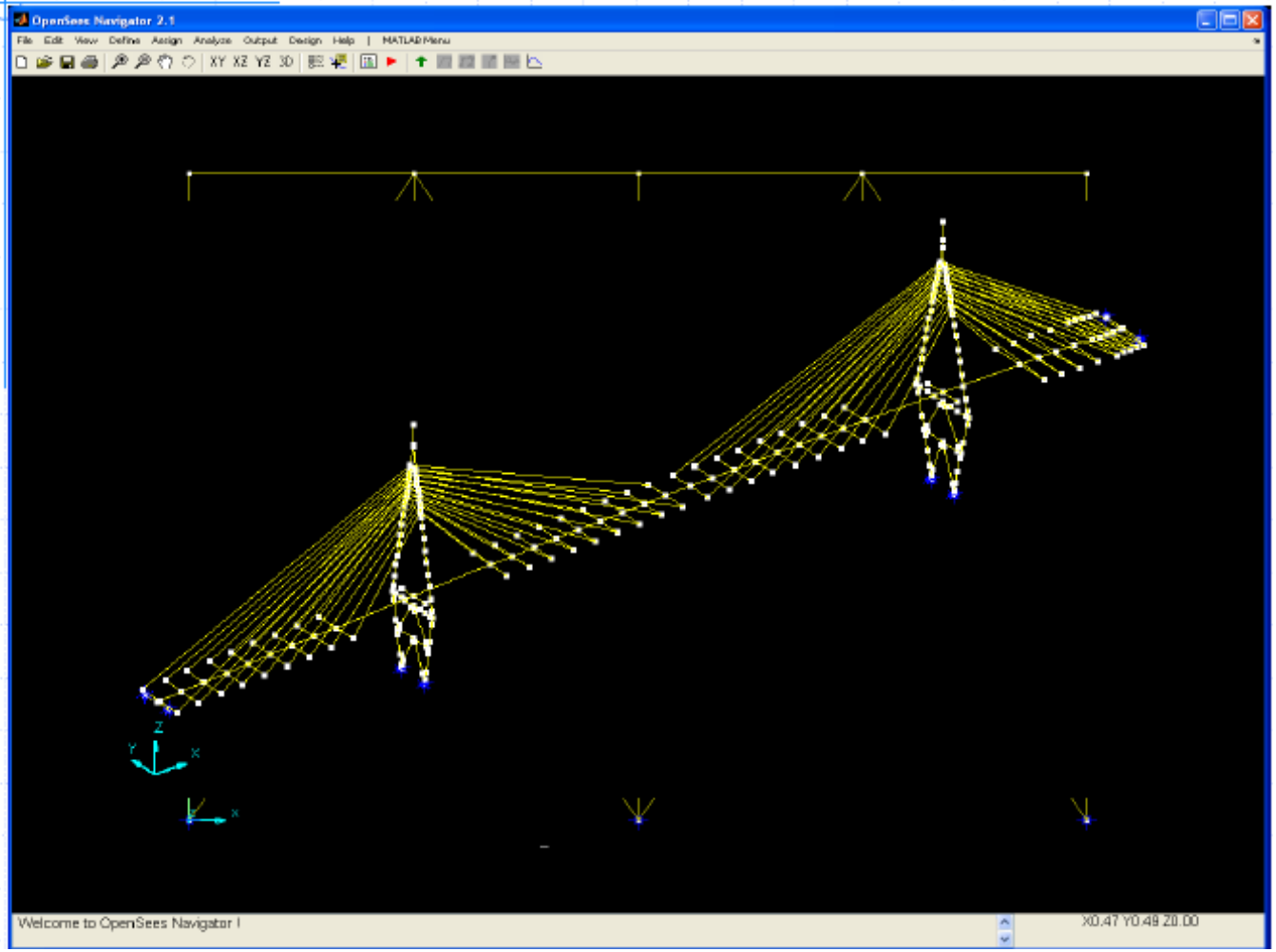
Axial Force



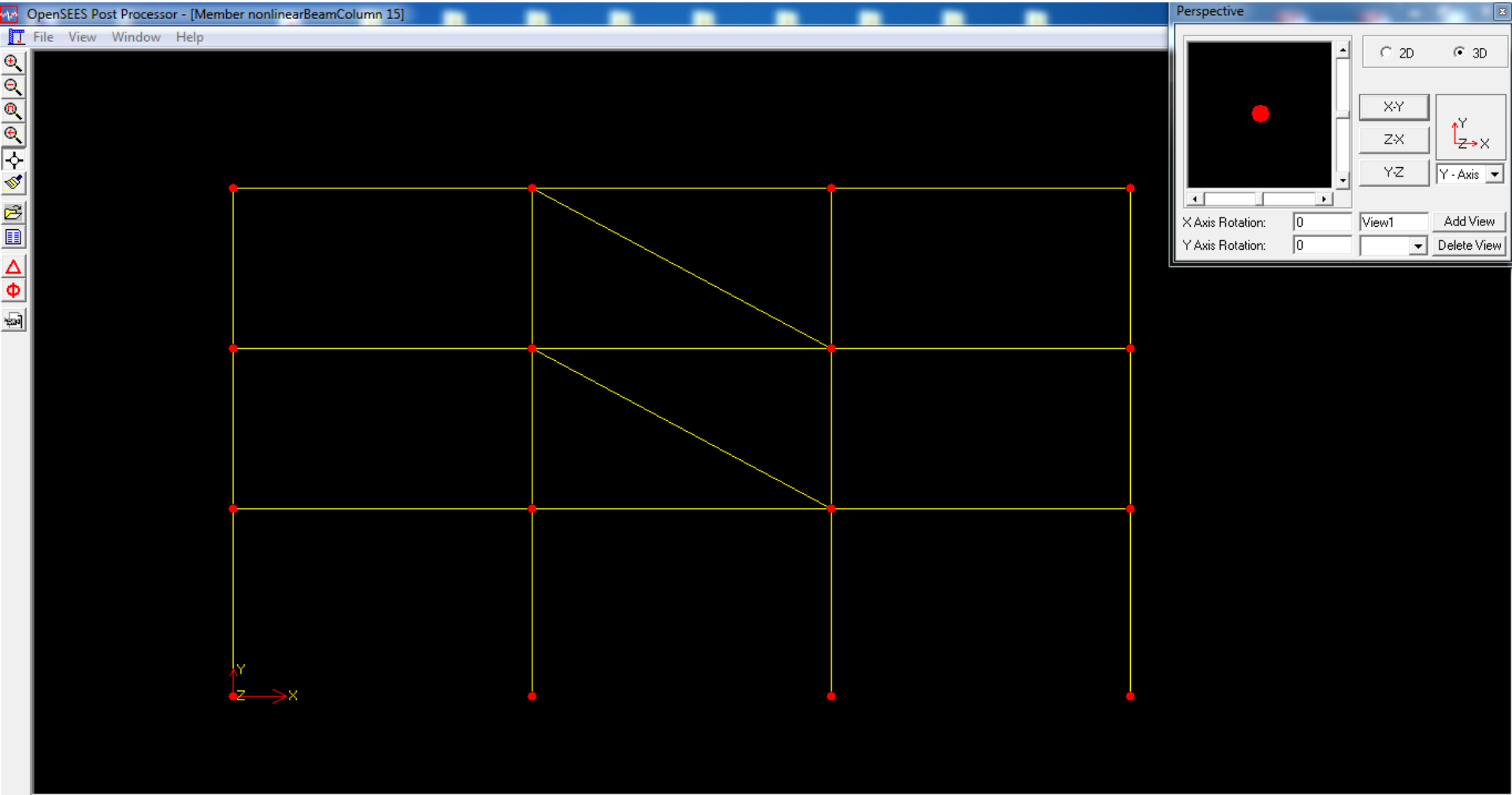
Axial Strain

2. OpenSees Navigator

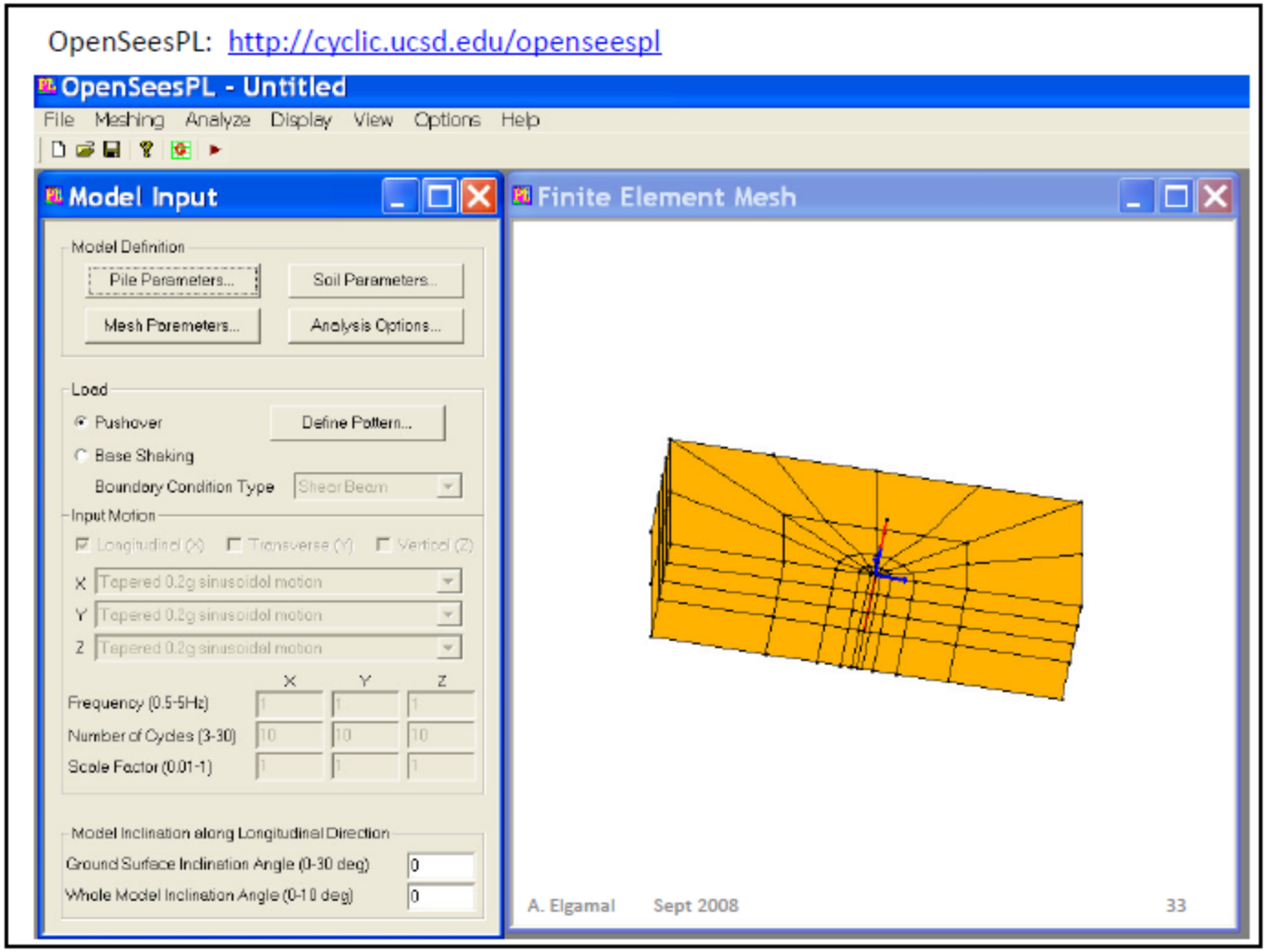
OpenSees Navigator



3. OpenSees Post Processor (OSP)



4. OpenSeesPL (Soil and Pile Modeling)

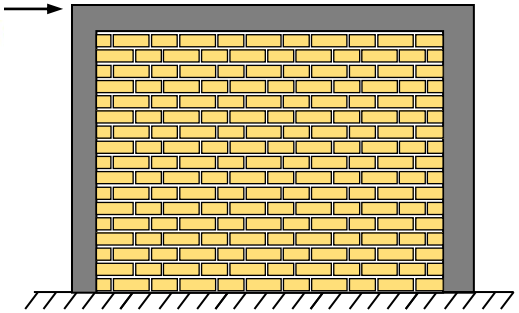


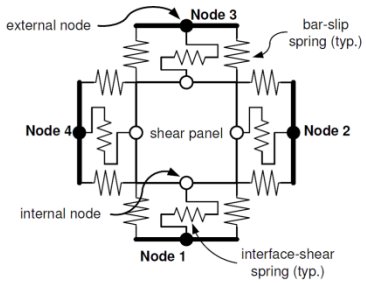
Finite Element Analysis Softwares

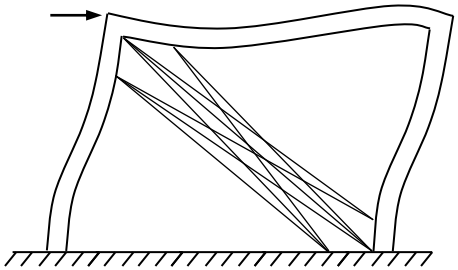
- Micro modeling

  ABAQUS, ANSYS, DIANA

  NASTRAN, OPENSEES



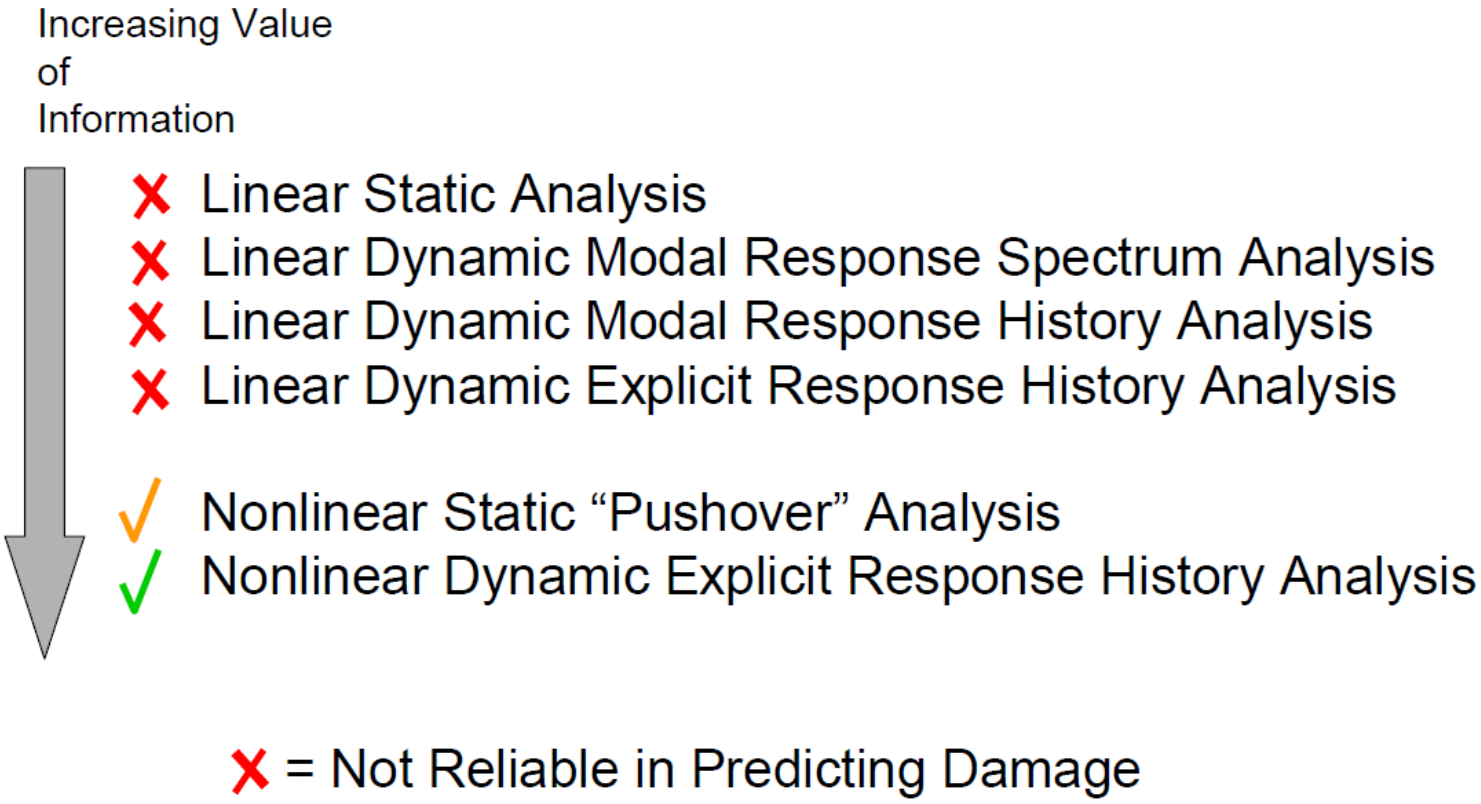




- Macro Modeling

  ETABS, SAP2000, PERFORM, DRAIN, NONLIN-Pro, IDARC, OPENSEES

How to Compute Performance-Based Deformation Demands?



DRAIN-2Dx is old technology, but it represents the basic state of the practice. The state of the art is being advanced through initiatives such as PEER's OpenSees Environment.(Reference: FEMA technical report 15-5-a)

Why OpenSees

- Advantages:

  Very Fast=> Timesaver

  Open-source => Adding Some Codes

  Free License => Easy Paper Submission

  Text File Output =>Little H.D.D. Space Consumption

  Flexible Programming (TCL) => Easy Parametric Studies

  Very Strong Analysis Engine => Easy Nonlinear Analysis

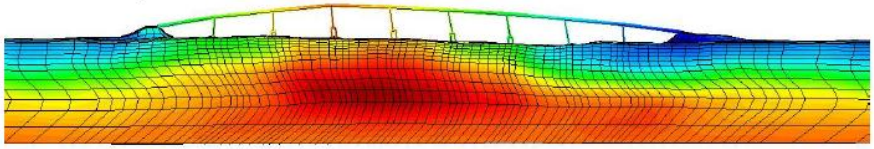
- Disadvantages:

  No fully developed pre or post processors yet available for model development and visualization

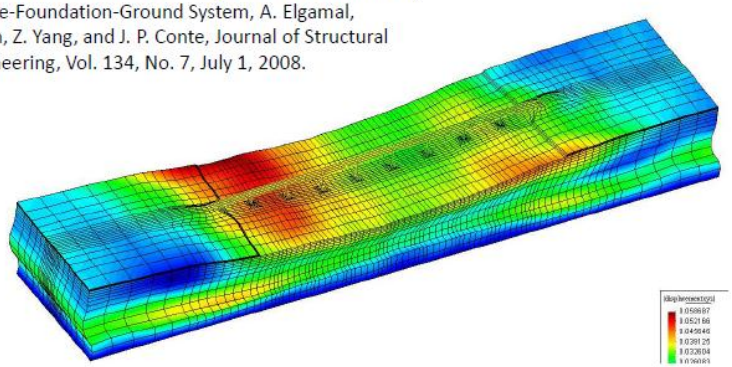
  Code is under development and still being fine-tuned

Bridge-Soil-Pile Modeling

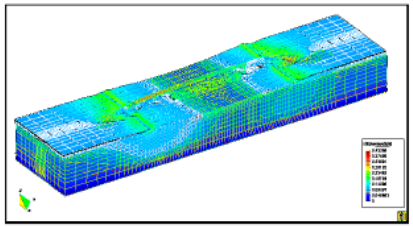
Numerical Analysis

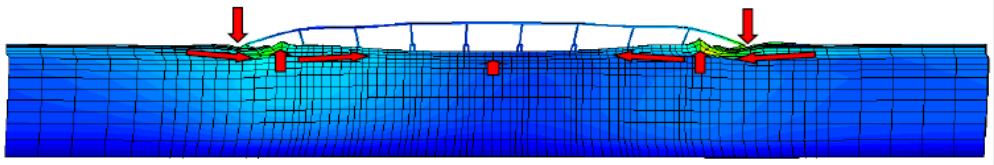


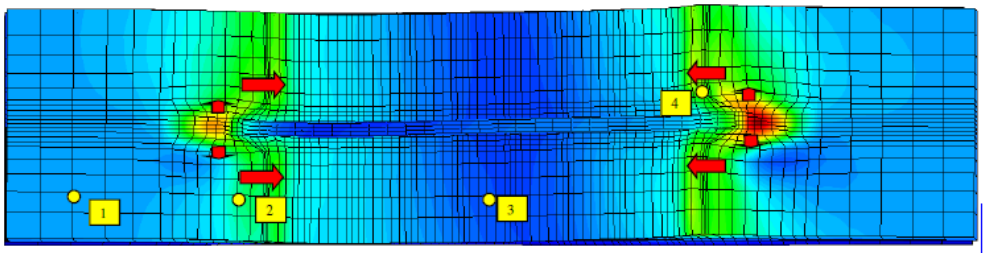
Three-Dimensional Seismic Response of Humboldt Bay Bridge-Foundation-Ground System, A. Elgamal, L. Yan, Z. Yang, and J. P. Conte, Journal of Structural Engineering, Vol. 134, No. 7, July 1, 2008.



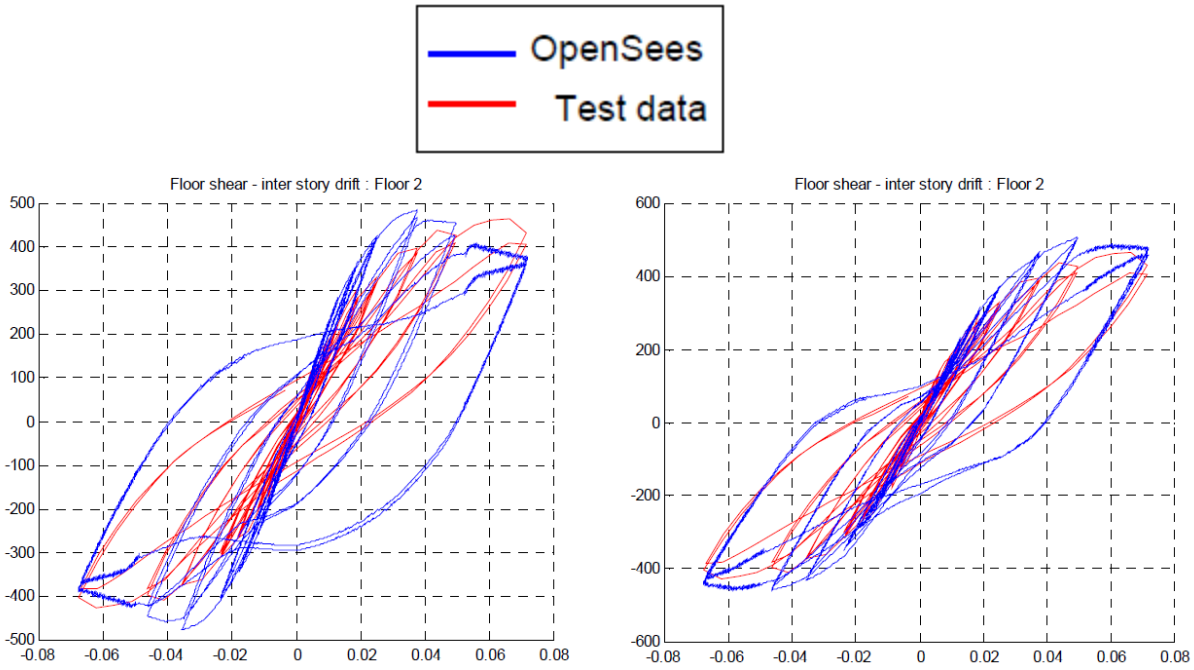
Elevation and Plan View of Residual Deformation (Scaling Factor = 50)



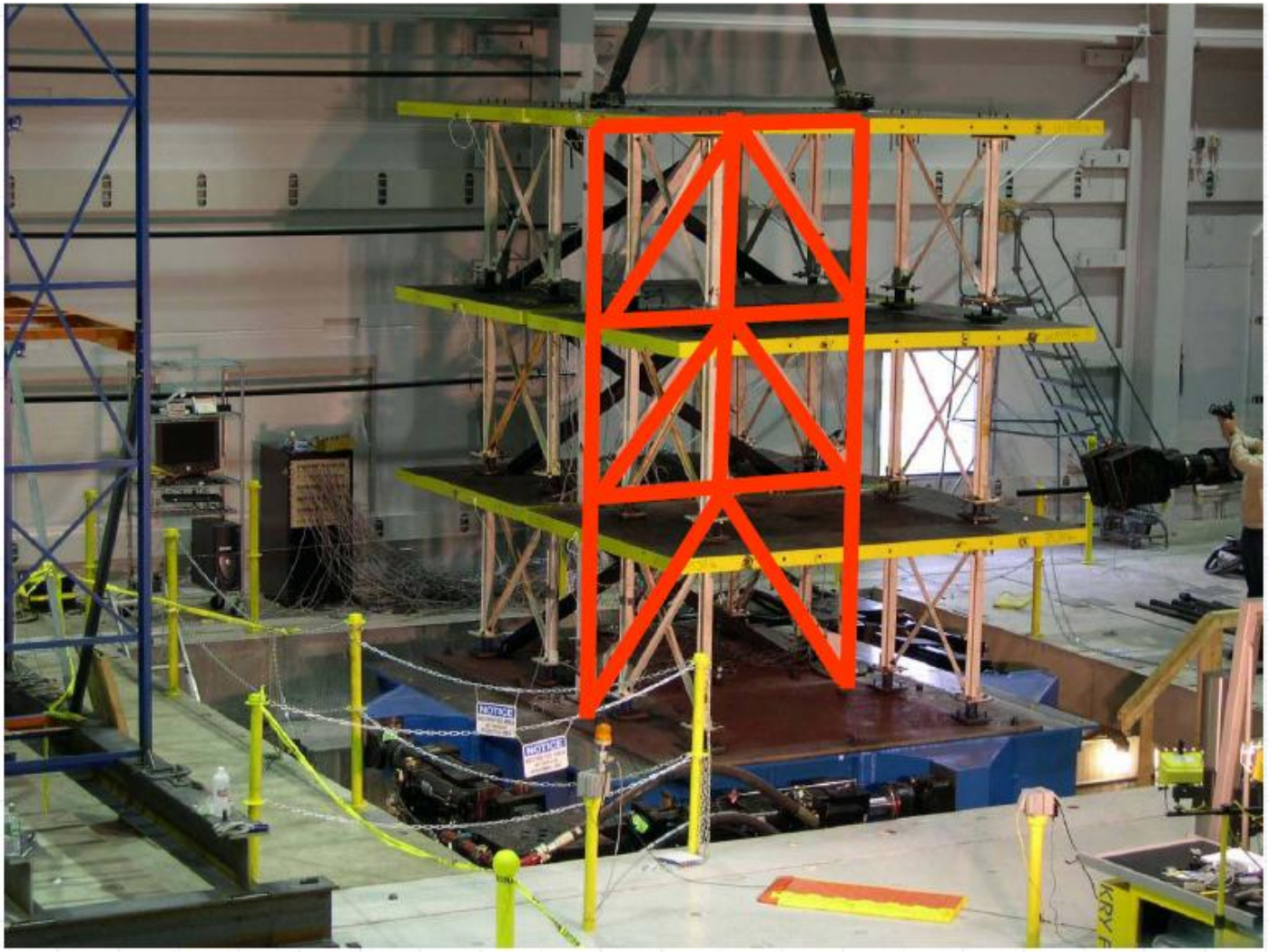


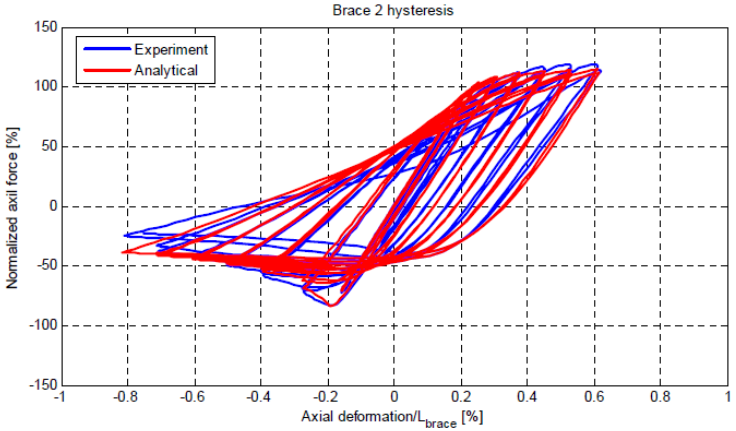


And Why do Finite Element Analysis NCEER frame tested at the Taiwan facility

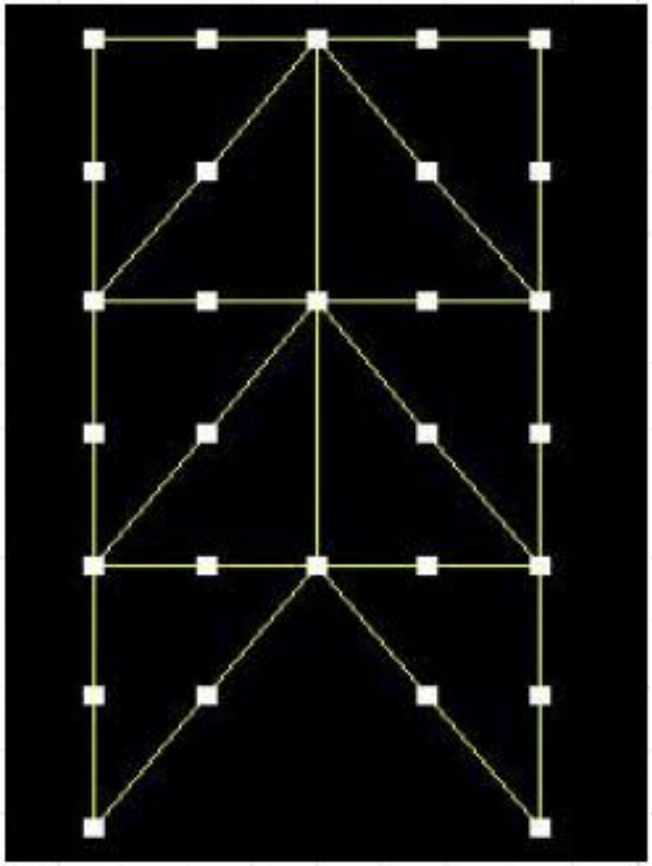


Buffalo Shaking Table Test





Experimental Testing



Analytical Simulation

Objective of User Workshop

- Describe modeling and analysis capability, including: element, section, material.
- Overview of applications, structural not geotechnical.
- Show specific examples of nonlinear analysis.
- Motivation to use OpenSees for your simulation problems….

What Should be Your Expectations?

- OpenSees is a research tool at this time, but fairly stable for regular use.
- As with any nonlinear analysis, it requires careful consideration of model and interpretation of results.
- It is under continual development by students, faculty and other researchers.
- It is not bullet-proof.
- An investment of time and learning is required.
- The OpenSees open-source community requires contributions for the community to succeed.

Any Questions or Statements?

Basic Modeling

What is Tcl

- Tcl is a dynamic programming language.
- It is a string based command language.
- Variables and variable substitution
- Expression evaluation
- Basic control structures (if , while, for, foreach)
- Procedures
- File manipulation
- Sourcing other files.

Comand syntax:

command arg1 arg2 …

- Help

1. http://www.tcl.tk/man/tcl8.5/tutorial/tcltutorial.html

Tcl Scripting

- *Variables* and variable substitution

```
>set a 1
1
>set b a
a
>set b $a
1
>set b $a$a
11
```

- *Expression* Evaluation

```
>expr 2+3
5
>set b [expr 2+$a]
3
>set b [expr 2+$a.$a]
3.1
```

- *Lists*

```
>set a {9 i c c  e}
9 i c c e
>set La [llength $a]
5
>set a_0 [lindex $a 0]
9
>lappend a OpenSees
9 i c c e OpenSees
```

- *file manipulation*

```
>set txt [open temp.out w+]
file1792158
>puts $txt “Hello World”
>close $txt
>type temp.out
Hello World
```

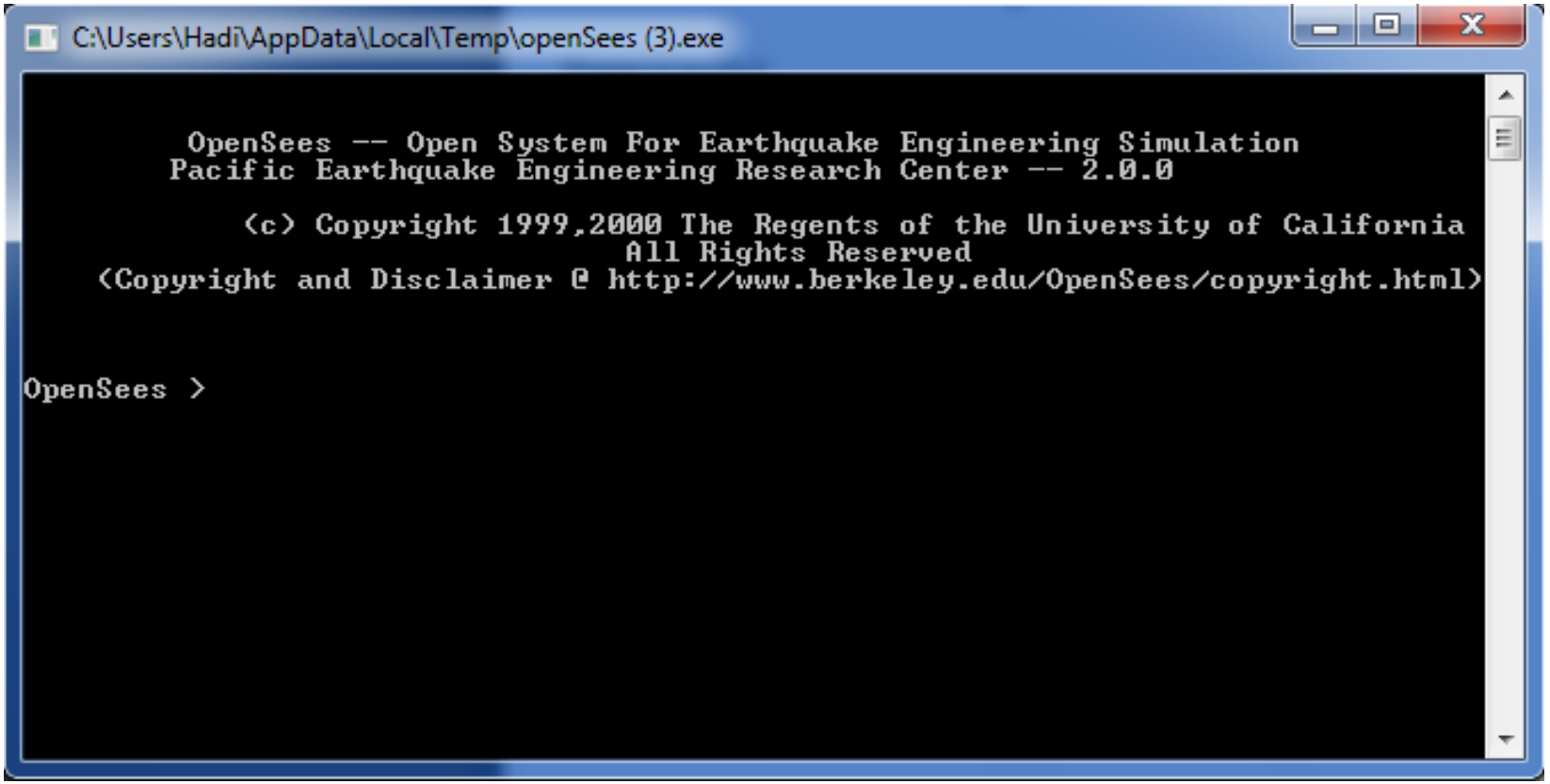
- *procedures & control structures*

```
> for {set i 1} {$i < 10} {incr
i 1} {
puts “i equals $i”
}
>foreach i {9 i c c e} {
puts “ i is $i”
}
>proc comp {a b} {
if {$a < $b} {
puts “$a is lower than $b”
} else {
if {$a > $b} {
puts “$a is greater than $b”
} else { puts “$a is equal $b”}
}
}
```

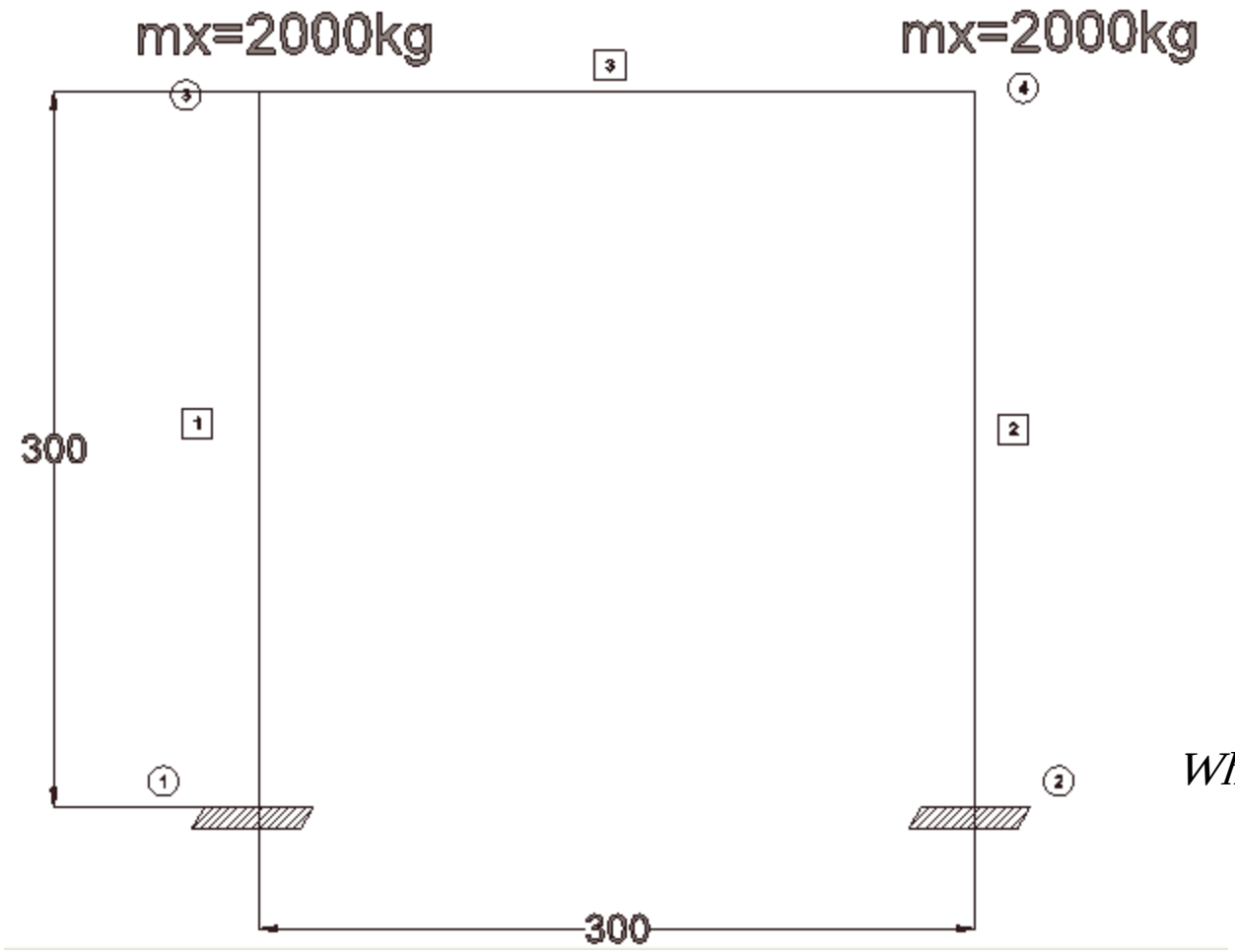
```
>source example.tcl
```

OpenSees.exe

- There is no GUI!



Example 1-Eigen Value Problem



$$I = 1.943e-5\ m^4$$

$$A = 2.85e-3\ m^2$$

$$E = 2.e11\ \frac{N}{m^2}$$

What is First Modal Period?

ModelBuilder Command

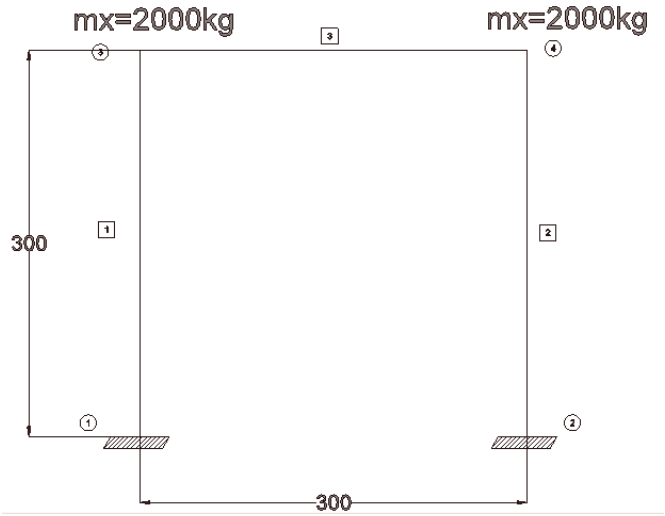
Basic ModelBuilder

model Basic -ndm $ndm <-ndf $ndf>

2D Model:	3D Model:
ndm = 2 ndf = 2 or 3	ndm = 3 ndf = 3 or 6

Example 1-Eigen Value Problem

```
wipe

model basic -ndm 2 -ndf 3
```



Modeling Commands

Domain

node $nodeTag (ndm $coords)

mass $nodeTag (ndf $MassValues)

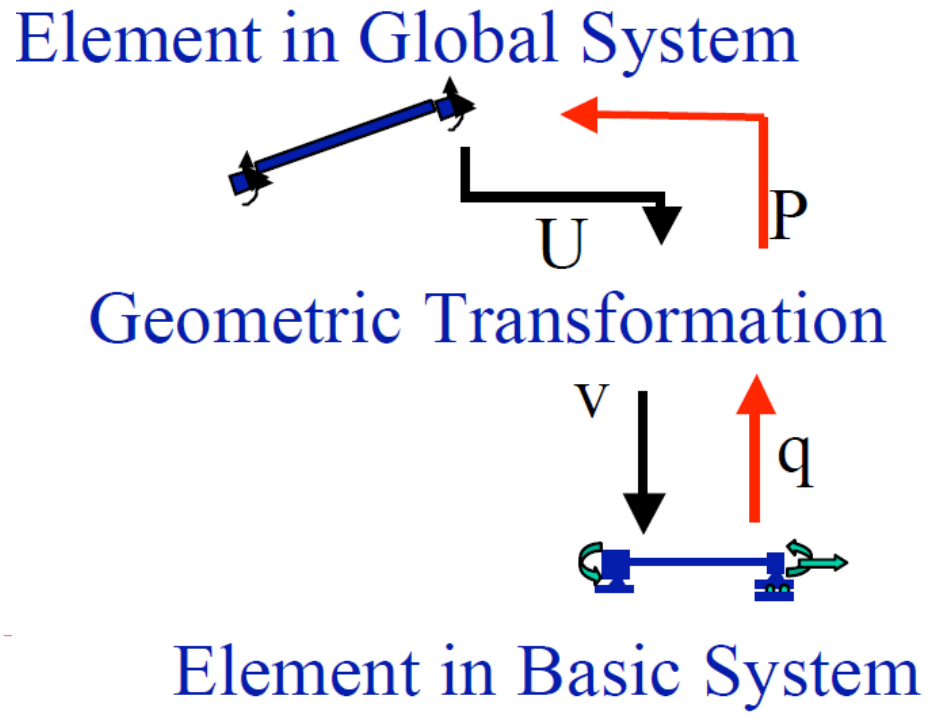
- **Geometric Transformation**
  Linear , PDelta , Corotational

geomTransf Linear $transfTag

- **Single-Point Constraints**

fix $nodeTag (ndf $ConstrValues)

- **Multi-Point Constraints**
  equalDOF , rigidDiaphragm , rigidLink

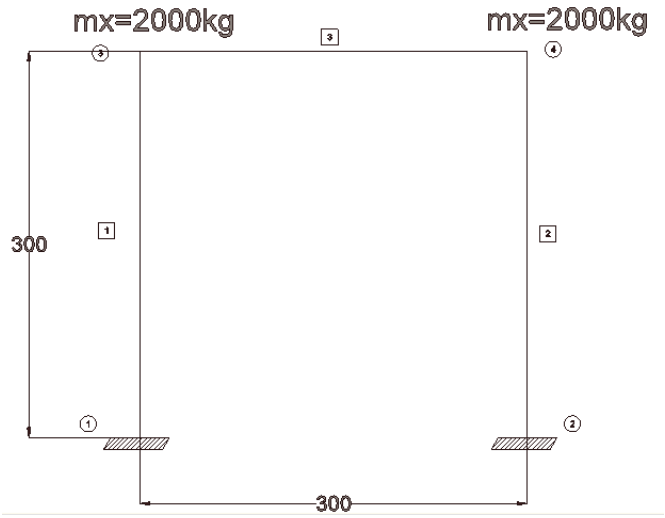


Example 1-Eigen Value Problem

wipe

model basic -ndm 2 -ndf 3

```
node 1 0. 0.
node 2 3. 0.
node 3 0. 3.
node 4 3. 3.

fix 1 1 1 1
fix 2 1 1 1

mass 3 2000. 0. 0.
mass 4 2000. 0. 0.

geomTransf Linear 1
```



Modeling Commands

- **Materials**

Uniaxial , nD Material , Section

Uniaxial	nD	Section
Elastic	Elastic	Elastic
ElasticPP	J2	Fiber
Hardening	DruckerPrager	
Concrete	TemplateElasto-Plasto	
Steel	FluidSolidPorous	
Hysteretic	PressureMultiYield(depen	
PY-TZ-QZ	dent, independent)	
Parallel	etc.	
Series		
Gap		
Fatigue		
etc.		

(over 250 material classes)

Modeling Commands

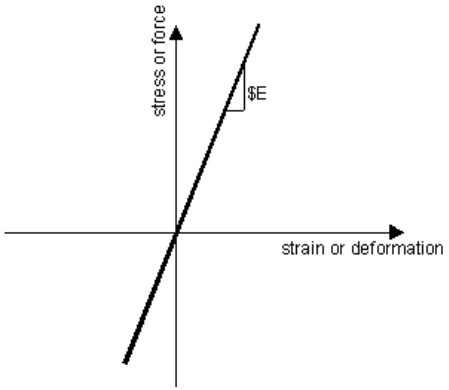
- **Materials**

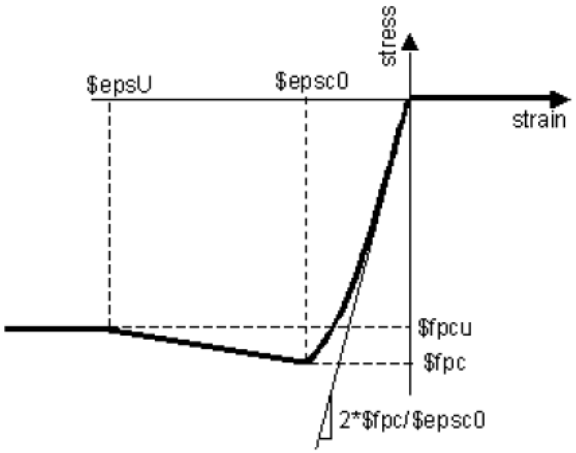
Uniaxial

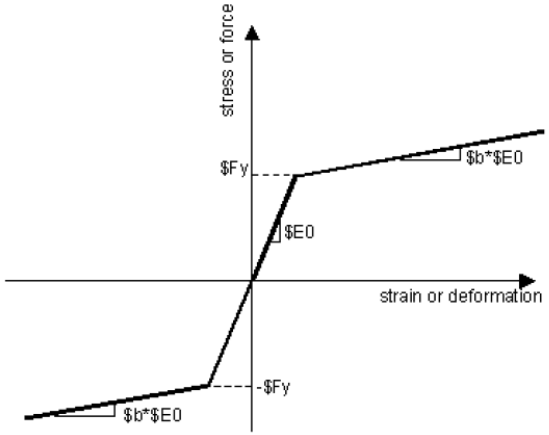
uniaxialMaterial Elastic $matTag $E

uniaxialMaterial Concrete01 $matTag $fpc $epsc0 $fpcu $epsU

uniaxialMaterial Steel01 $matTag $Fy $E0 $b







Modeling Commands

- **Elements**

  Truss , Elastic Beam Column , Zero Length , Nonlinear Beam Column (force, displacement) , Beam With Hinges , Quad , Shell , Brick , Joint , etc.

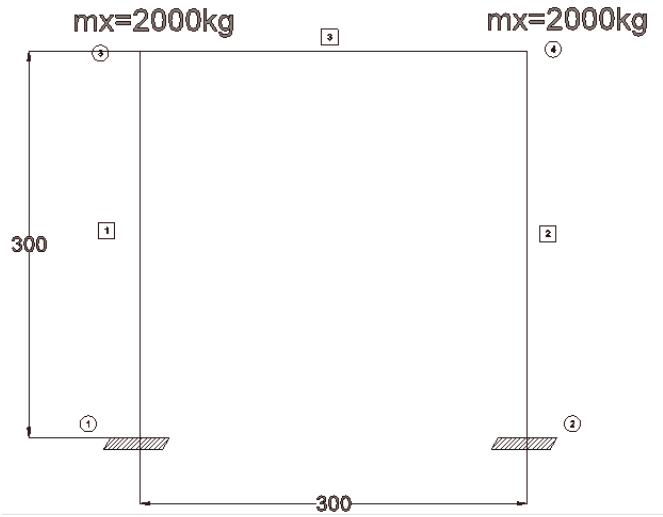
  > 100 element classes

```
element truss $eleTag $iNode $jNode $A $matTag
```

```
element elasticBeamColumn $eleTag $iNode $jNode $A $E $Iz $transfTag
```

```
element nonlinearBeamColumn $eleTag $iNode $jNode $numIntgrPts $secTag $transfTag
```

Example 1-Eigen Value Problem




```
wipe

model basic -ndm 2 -ndf 3

node 1 0. 0.
node 2 3. 0.
node 3 0. 3.
node 4 3. 3.

fix 1 1 1 1
fix 2 1 1 1

mass 3 2000. 0. 0.
mass 4 2000. 0. 0.

geomTransf Linear 1

element elasticBeamColumn 1 1 3 28.5e-4 2e11 1.943e-5 1
element elasticBeamColumn 2 2 4 28.5e-4 2e11 1.943e-5 1
element elasticBeamColumn 3 3 4 28.5e-4 2e11 1.943e-5 1
```

Modeling Commands

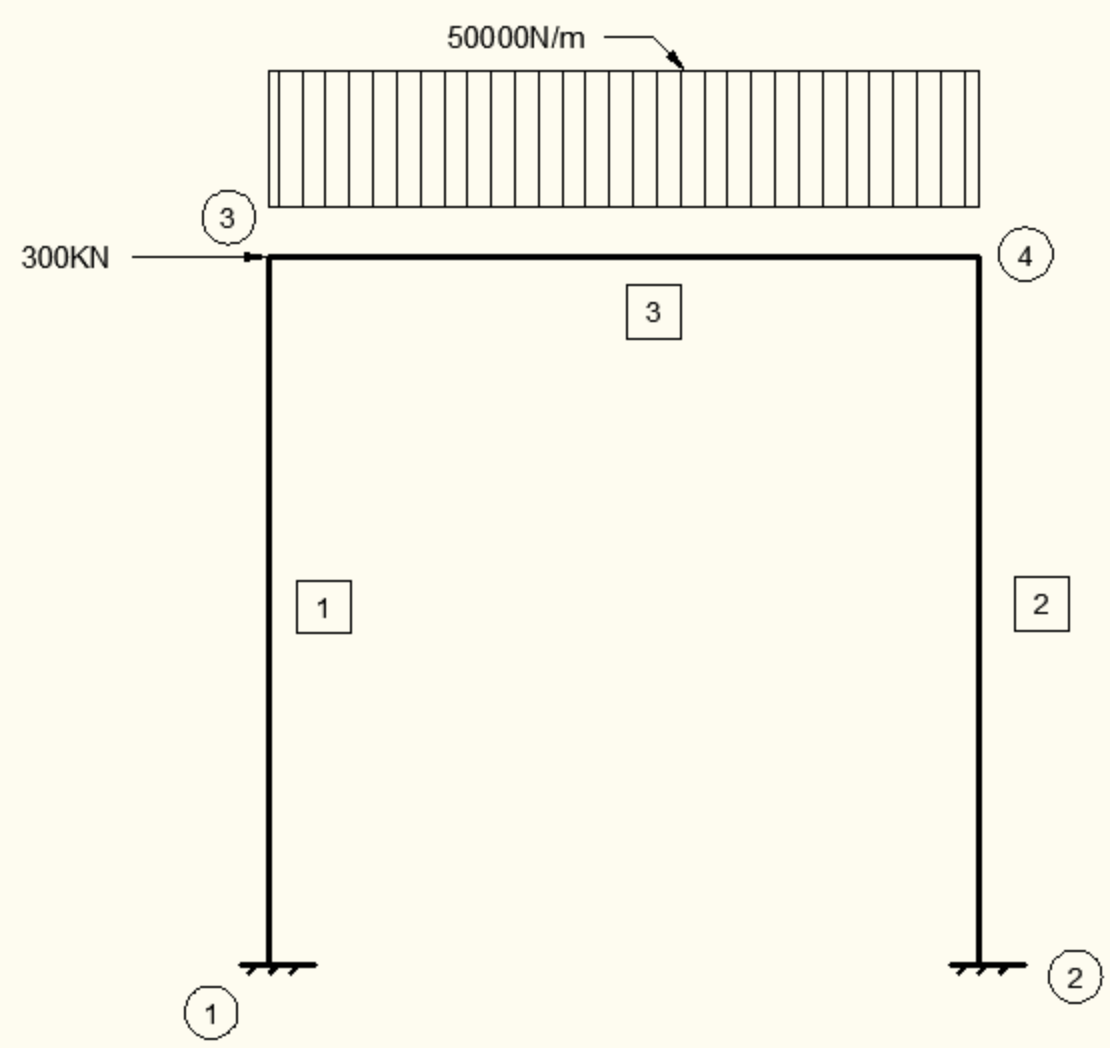
- **Eigen Command**

eigen $numEigenvalues

```
wipe

model basic -ndm 2 -ndf 3

node 1 0. 0.
node 2 3. 0.
node 3 0. 3.
node 4 3. 3.

fix 1 1 1 1
fix 2 1 1 1

mass 3 2000. 0. 0.
mass 4 2000. 0. 0.

geomTransf Linear 1

element elasticBeamColumn 1 1 3 28.5e-4 2e11 1.943e-5 1
element elasticBeamColumn 2 2 4 28.5e-4 2e11 1.943e-5 1
element elasticBeamColumn 3 3 4 28.5e-4 2e11 1.943e-5 1

puts "First Eigen Value is: [eigen 1]
First Mode Period is: [expr 2*3.1415/pow([eigen 1],0.5)]"
```

SAP2000 OpenSees

Example 2-1-Gravity Loading



$$I = 1.943e - 5\ m^4$$

$$A = 2.85e - 3\ m^2$$

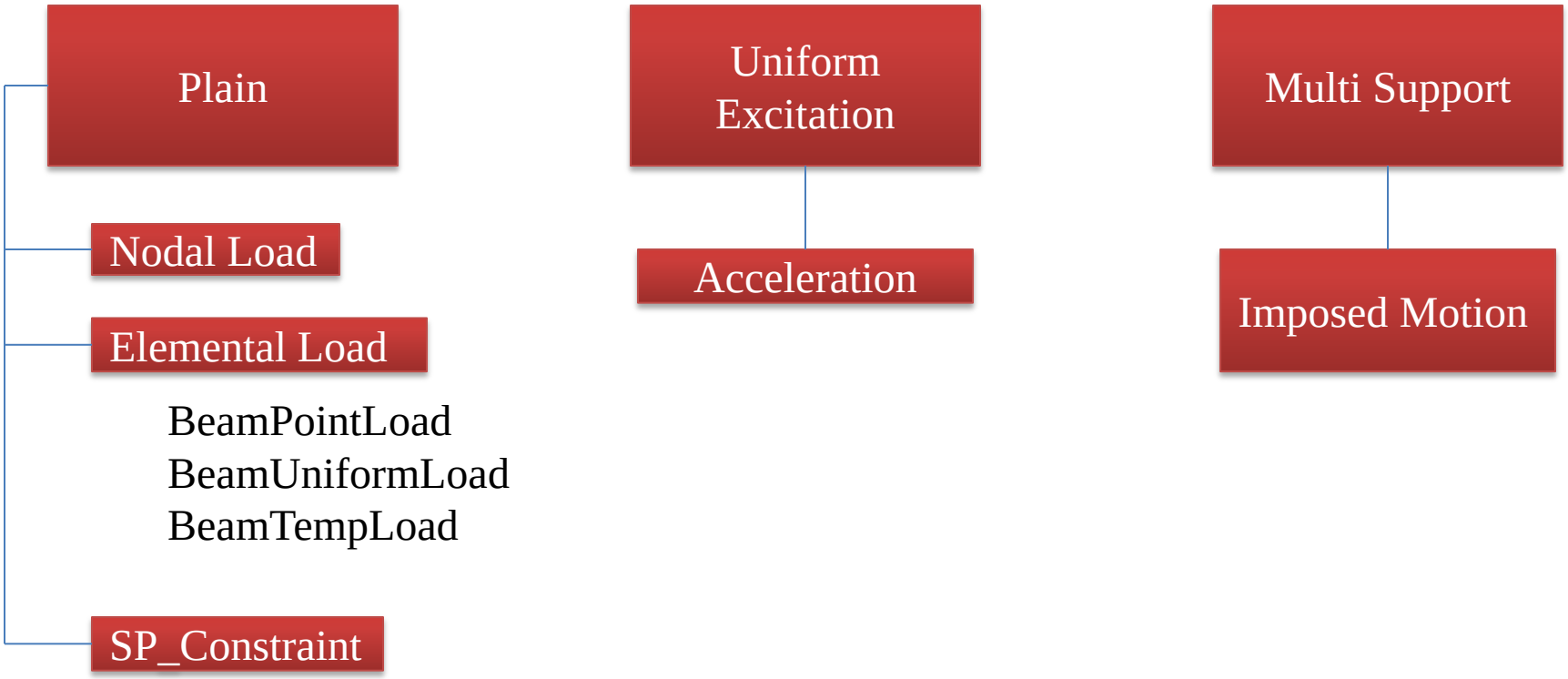
$$E = 2.e11\frac{N}{m^2}$$

Total Displacement of Node 4?

Modeling Commands

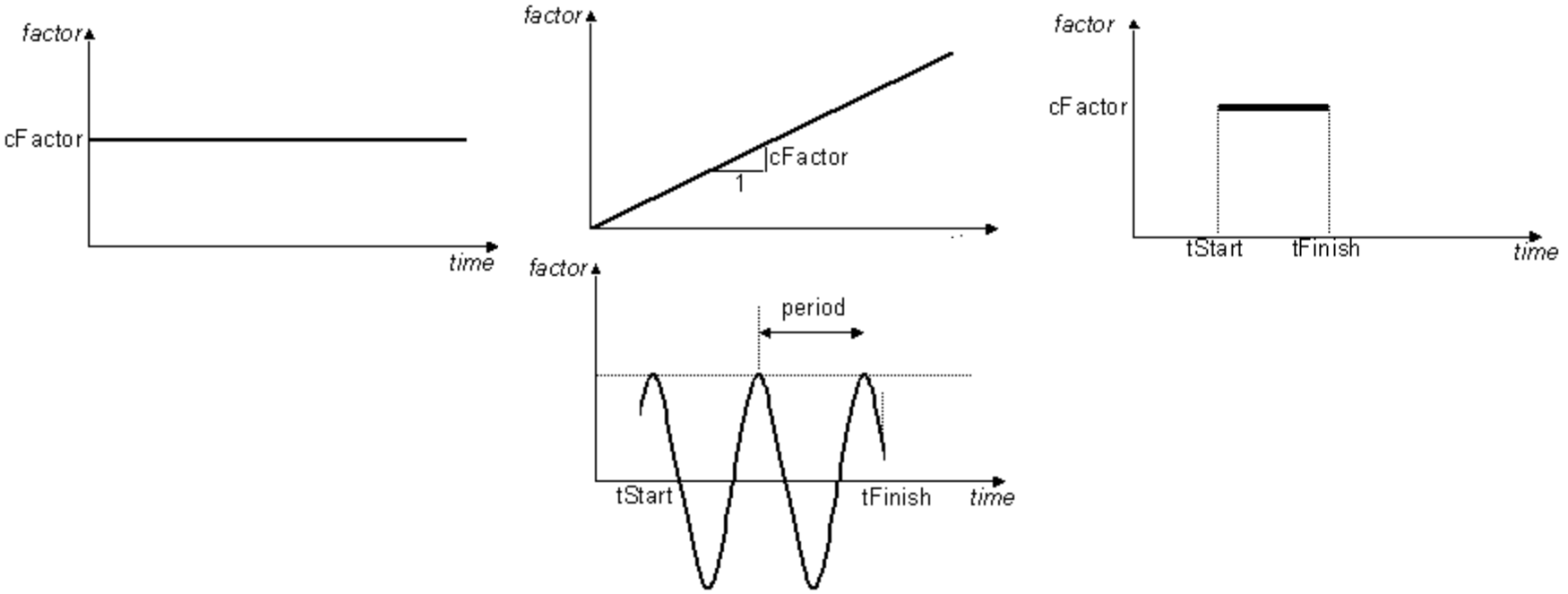
- **Load Pattern**

  Plain , Uniform Excitation , Multi Support



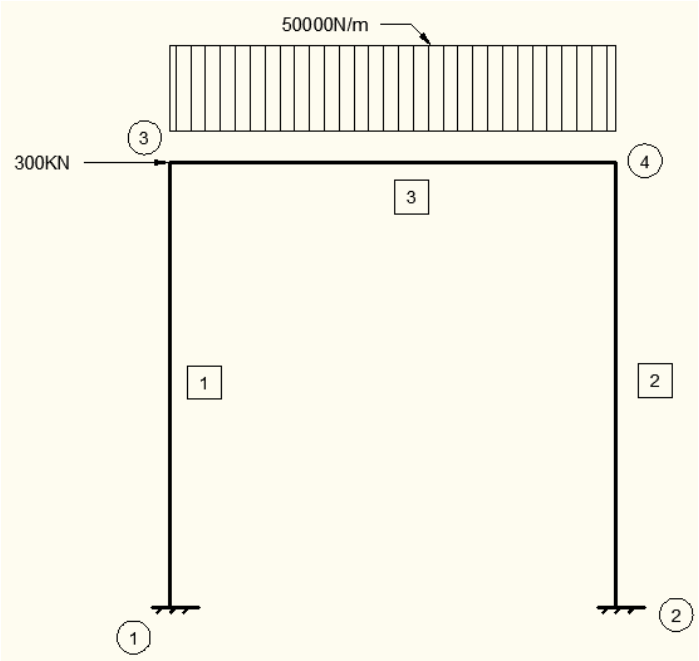
Modeling Commands

- **Time Series (Functions)**
  Constant , Linear , Rectangular , Sine , Path



- **Series -dt dt? -values {list of points} <-factor cFactor?>**
- **Series -time {list of times} -values {list of points} <-factor cFactor?>**
- **Series -dt dt? -filePath fileName? <-factor cFactor?>**
- **Series -fileTime fileName1? -filePath fileName2? <-factor cFactor?>**

Example 2-1-Gravity Loading




```
wipe

model basic -ndm 2 -ndf 3

node 1 0. 0.
node 2 3. 0.
node 3 0. 3.
node 4 3. 3.

fix 1 1 1 1
fix 2 1 1 1

mass 3 2000. 0. 0.
mass 4 2000. 0. 0.
geomTransf Linear 1

element elasticBeamColumn 1 1 3 28.5e-4 2e11 1.943e-5 1
element elasticBeamColumn 2 2 4 28.5e-4 2e11 1.943e-5 1
element elasticBeamColumn 3 3 4 28.5e-4 2e11 1.943e-5 1

pattern Plain 1 Linear {
eleLoad -ele 3 -type -beamUniform -5e4
load 3 3.e5 0. 0.
}
```

Output Options

There is NO OUTPUT until you request it from OpenSees!

There are 4 options to obtain output:

1. **recorder** command

   Records a specific output to a file or database

   recorder $type $arg1 $arg2 …

2. **puts** command

   Puts a specific output or variable to monitor or file stream

   puts <$fileID> $string

3. **print** command

   Prints a specific output or data existed in the domain to monitor or file stream

   print <-file $fileName> <-node $nd1 $nd2 ..> <-ele $ele1 $ele2 …>

4. **recorder display** command

Output Options

Node/EnvelopeNode Recorders

recorder Node <-file $fileName><-timeSeries $tsTag> <-time> <-node $tg1 $tg2 …> -dof $d1 $d2 .. disp
<-xml $fileName> <-nodeRange $tgS $tgE> vel
<-binary $fileName> <-region $rTag> accel
<-tcp $inetAddr> incrDisp
reaction

- The EnvelopeNode takes exactly same args as Node

recorder EnvelopeNode *<-file $fileName> <-timeSeries $tsTag> <-time> <-node $tg1 $tg2 …> -dof $d1 $d2 .. disp*
<-xml $fileName> <-nodeRange $tgS $tgE> vel
<-binary $fileName> <-region $rTag> accel
<-tcp $inetAddr> incrDisp
reaction

Output Options

Element/EnvelopeElement Recorders

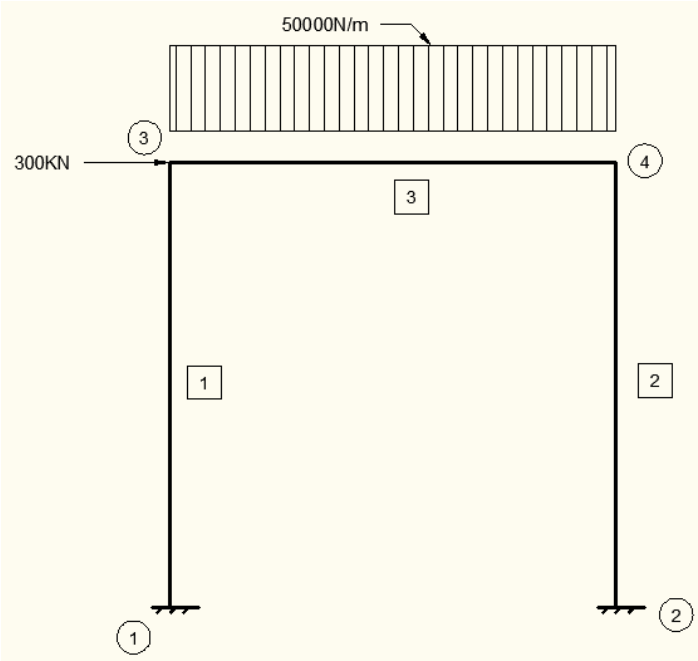
recorder Element <-file $fileName> <-time> <-ele $tg1 $tg2 …> $arg1 $arg2 …

The valid args for different elements

Elastic BCE:	Force BCE and BWHE:
force	*force*
	globalForce
	localForce
	plasticDeformation
	etc.

- The EnvelopeElement takes exactly same args

Example 2-1-Gravity Loading




```
wipe

model basic -ndm 2 -ndf 3

node 1 0. 0.
node 2 3. 0.
node 3 0. 3.
node 4 3. 3.

fix 1 1 1 1
fix 2 1 1 1

mass 3 2000. 0. 0.
mass 4 2000. 0. 0.
geomTransf Linear 1

element elasticBeamColumn 1 1 3 28.5e-4 2e11 1.943e-5 1
element elasticBeamColumn 2 2 4 28.5e-4 2e11 1.943e-5 1
element elasticBeamColumn 3 3 4 28.5e-4 2e11 1.943e-5 1

pattern Plain 1 Linear {
eleLoad -ele 3 -type -beamUniform -5e4
load 3 3.e5 0. 0.
}
```

```
recorder Node -file node4disp.out -time -node 4 -dof 1 2 3 disp
recorder Node -file node1reac.out -time -node 1 -dof 1 2 3 reaction
recorder Node -file node2reac.out -time -node 2 -dof 1 2 3 reaction
```

Example Analysis

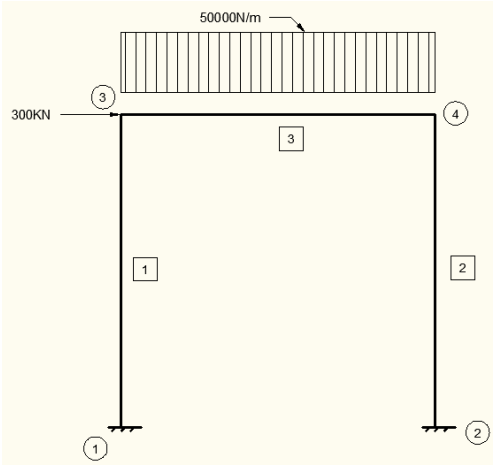
Static Linear Analysis with Load Control

```
constraints Plain
numberer Plain
system BandGeneral
test NormDispIncr 1.e-8 6
algorithm ModifiedNewton
integrator LoadControl 1
analysis Static
analyze 1
loadConst -time 0.0
```

Static Nonlinear Analysis with Load Control

```
constraints Plain
numberer Plain
system BandGeneral
test NormDispIncr 1.e-8 6
algorithm ModifiedNewton
integrator LoadControl 0.1
analysis Static
analyze 10
loadConst -time 0.0
```

Example 2-1-Gravity Loading




```
wipe

model basic -ndm 2 -ndf 3

node 1 0. 0.
node 2 3. 0.
node 3 0. 3.
node 4 3. 3.

fix 1 1 1 1
fix 2 1 1 1

mass 3 2000. 0. 0.
mass 4 2000. 0. 0.
geomTransf Linear 1

element elasticBeamColumn 1 1 3 28.5e-4 2e11 1.943e-5 1
element elasticBeamColumn 2 2 4 28.5e-4 2e11 1.943e-5 1
element elasticBeamColumn 3 3 4 28.5e-4 2e11 1.943e-5 1

pattern Plain 1 Linear {
eleLoad -ele 3 -type -beamUniform -5e4
load 3 3.e5 0. 0.
}
```

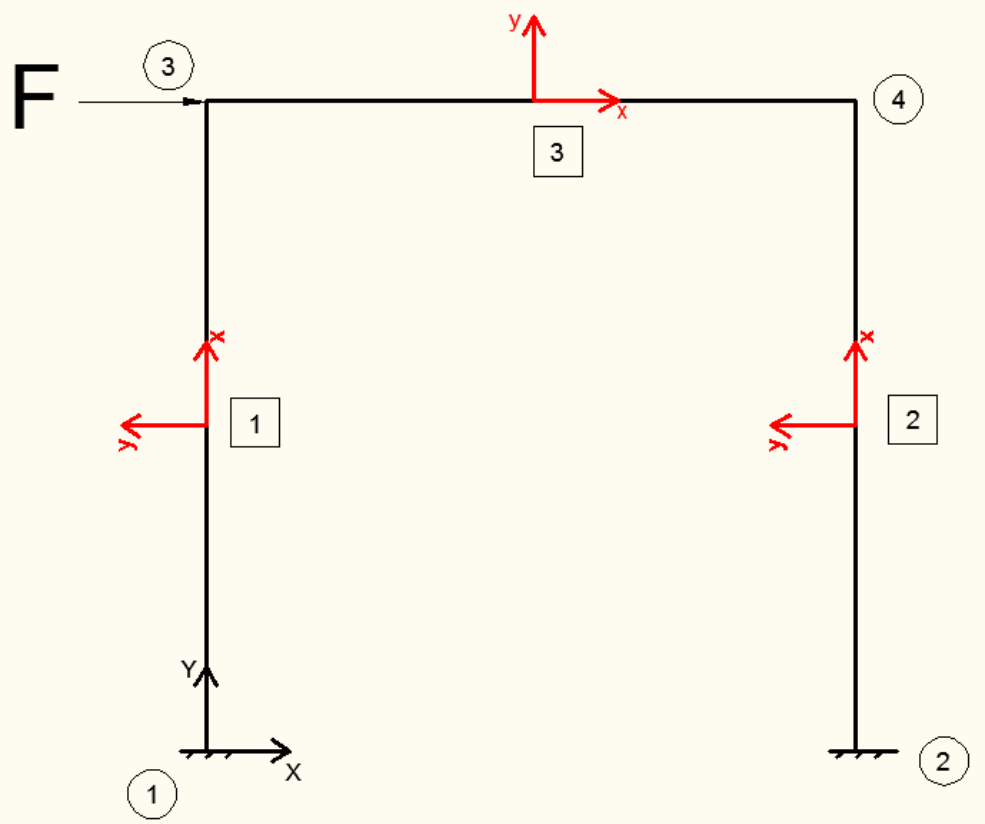
```
recorder Node -file node4disp.out -time -node 4 -dof 1 2 3 disp
recorder Node -file node1reac.out -time -node 1 -dof 1 2 3 reaction
recorder Node -file node2reac.out -time -node 2 -dof 1 2 3 reaction
```

```
constraints Plain
numberer Plain
system BandGeneral
test NormDispIncr 1.e-8 6
algorithm ModifiedNewton
integrator LoadControl 1
analysis Static
analyze 1
loadConst -time 0.0
```

SAP2000

OpenSees

Example 2-2-Linear Pushover



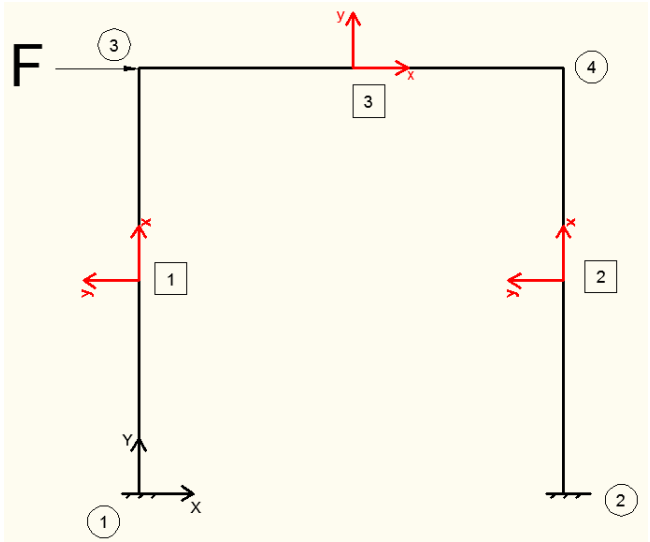
Push the frame to 0.1m displacement of Node 4 in X dir.

Example Analysis

Static Linear Analysis with Displacement Control

```
constraints Plain
numberer Plain
system BandGeneral
test NormDispIncr 1.e-8 6
algorithm ModifiedNewton
integrator DisplacementControl 4 1 0.001
analysis Static
analyze 100
loadConst -time 0.0
```

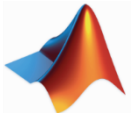
Example 2-2-Linear Pushover




```
wipe

model basic -ndm 2 -ndf 3

node 1 0. 0.
node 2 3. 0.
node 3 0. 3.
node 4 3. 3.

fix 1 1 1 1
fix 2 1 1 1

mass 3 2000. 0. 0.
mass 4 2000. 0. 0.
geomTransf Linear 1

element elasticBeamColumn 1 1 3 28.5e-4 2e11 1.943e-5 1
element elasticBeamColumn 2 2 4 28.5e-4 2e11 1.943e-5 1
element elasticBeamColumn 3 3 4 28.5e-4 2e11 1.943e-5 1

pattern Plain 1 Linear {
load 3 1000. 0. 0.
}
```

```
recorder Node -file node4disp.out -time -node 4 -dof 1 2 3 disp
recorder Node -file node1reac.out -time -node 1 -dof 1 2 3 reaction
recorder Node -file node2reac.out -time -node 2 -dof 1 2 3 reaction
```

```
constraints Plain
numberer Plain
system BandGeneral
test NormDispIncr 1.e-8 6
algorithm ModifiedNewton
integrator DdisplacementControl 4 1 0.001
analysis Static
analyze 100
loadConst -time 0.0
```



OpenSees

Any Questions or Statements?

Nonlinear Modeling and Analysis

Why Nonlinear Analysis:

- Geometric Nonlinearities
- Material nonlinearities
- Contact nonlinearities

Nonlinear Analysis is Harder

- It requires much more thought when setting up the model
- It requires more thought when setting up the analysis
- It takes more computational time.
- It does not always converge.
- It does not always converge to the correct solution.

BUT Most Problems Require
Nonlinear Analysis

CHECK YOUR MODEL!

Modeling Commands

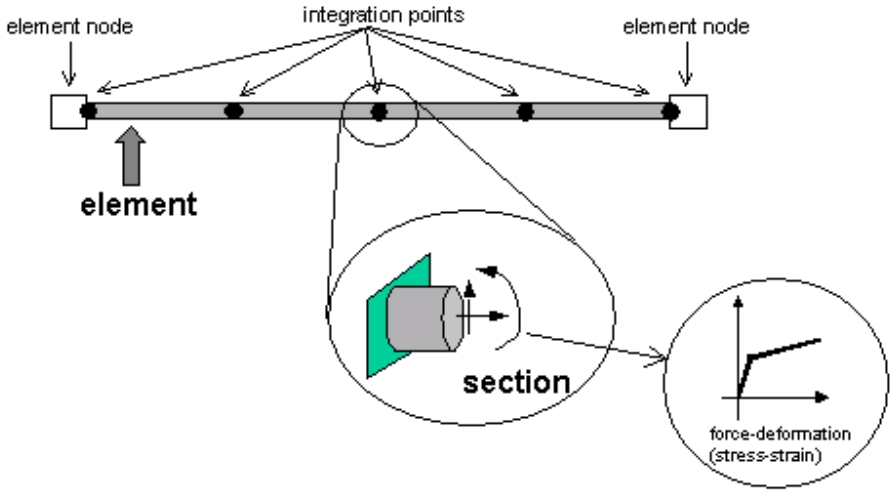
- **Section Command**

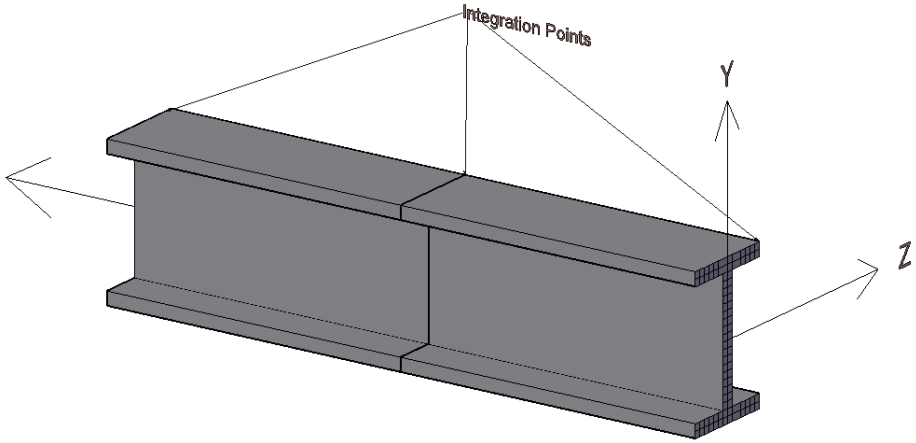
  What is a section?

  A section defines the stress resultant force-deformation response at a cross section of a beam-column or plate element.

  Types of sections:

  - Elastic
  - Resultant
  - Fiber



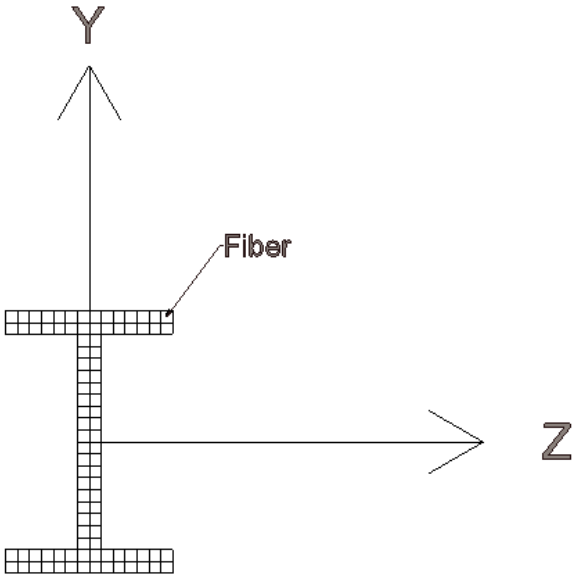


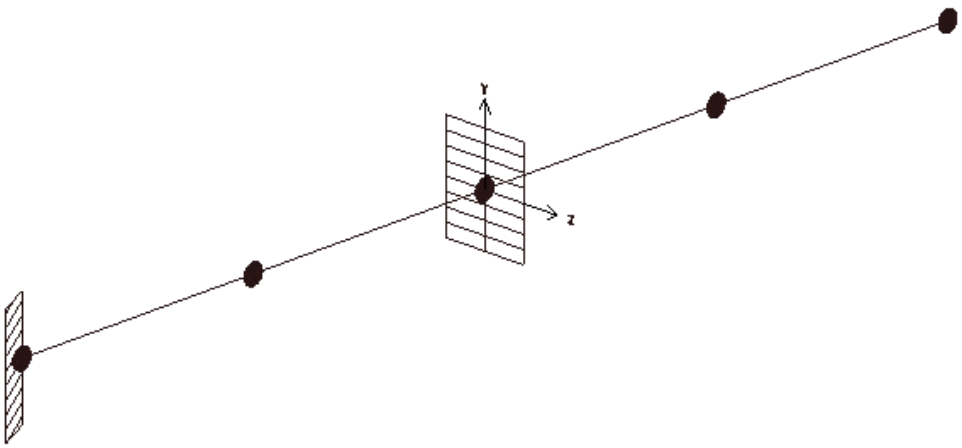
Modeling Commands

- **Fiber Section**

  The Fiber Section object is composed of Fiber objects.

```
section Fiber $secTag {
        fiber <fiber arguments>
        patch <patch arguments>
        layer <layer arguments>
}
```

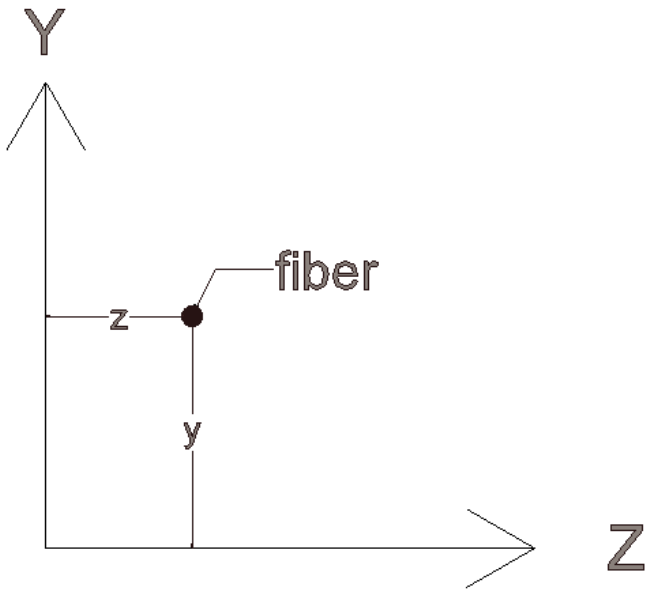


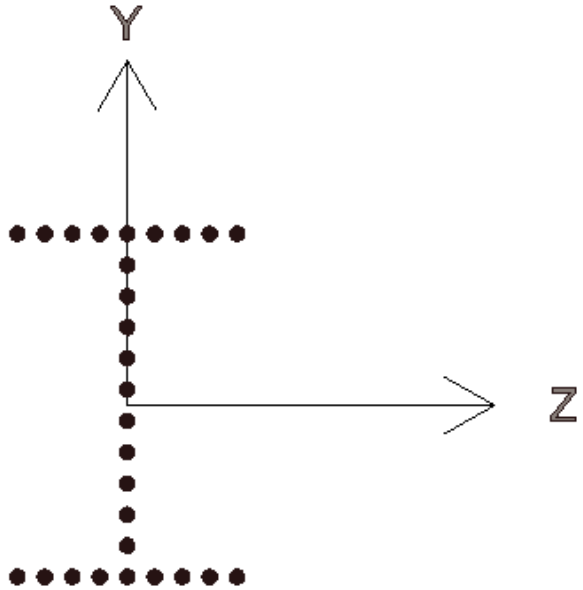


Modeling Commands

- **Fiber command**

fiber $yLoc $zLoc $A $matTag

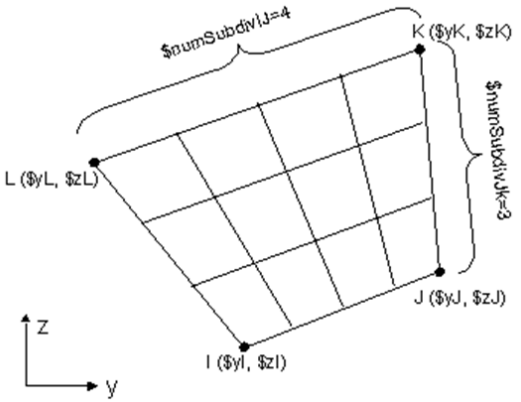


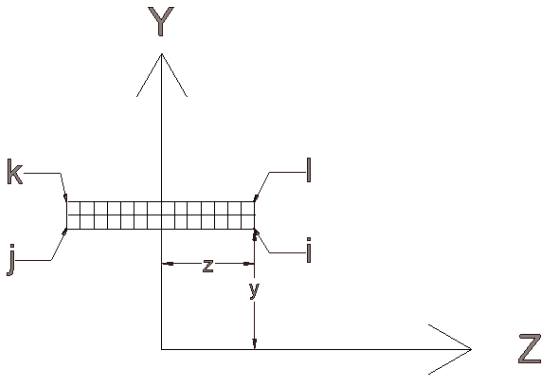


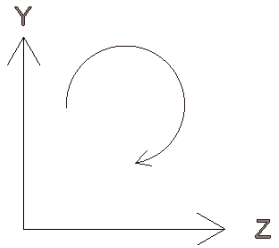
Modeling Commands

- **Patch command**

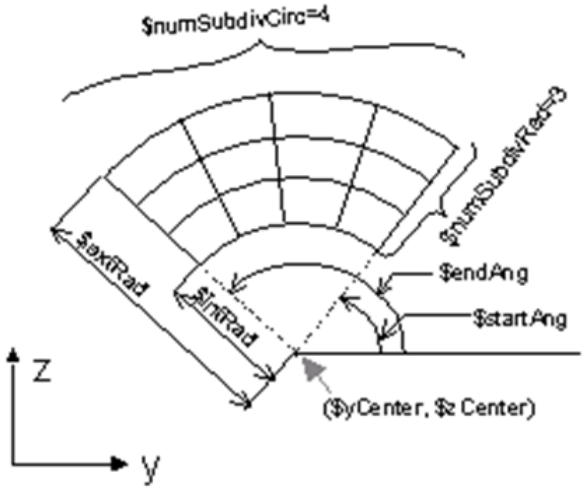
patch quad $matTag $numSubdivIJ $numSubdivJK $yI $zI $yJ $zJ $yK $zK $yL $zL







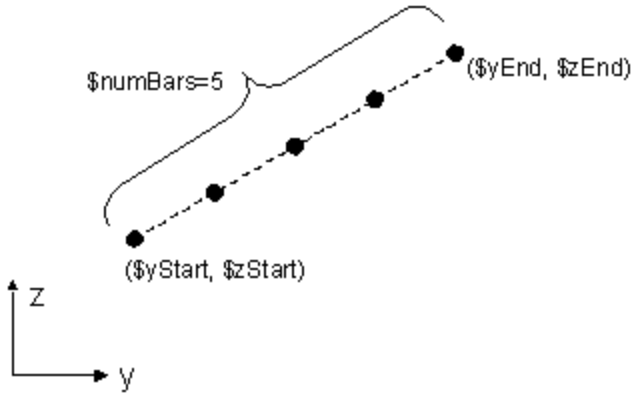
patch circ $matTag $numSubdivCirc $numSubdivRad $yCenter $zCenter $intRad $extRad <$startAng $endAng>



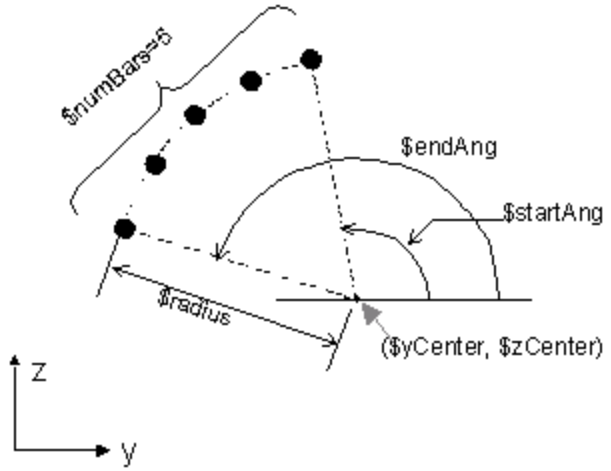
Modeling Commands

- **Layer command**

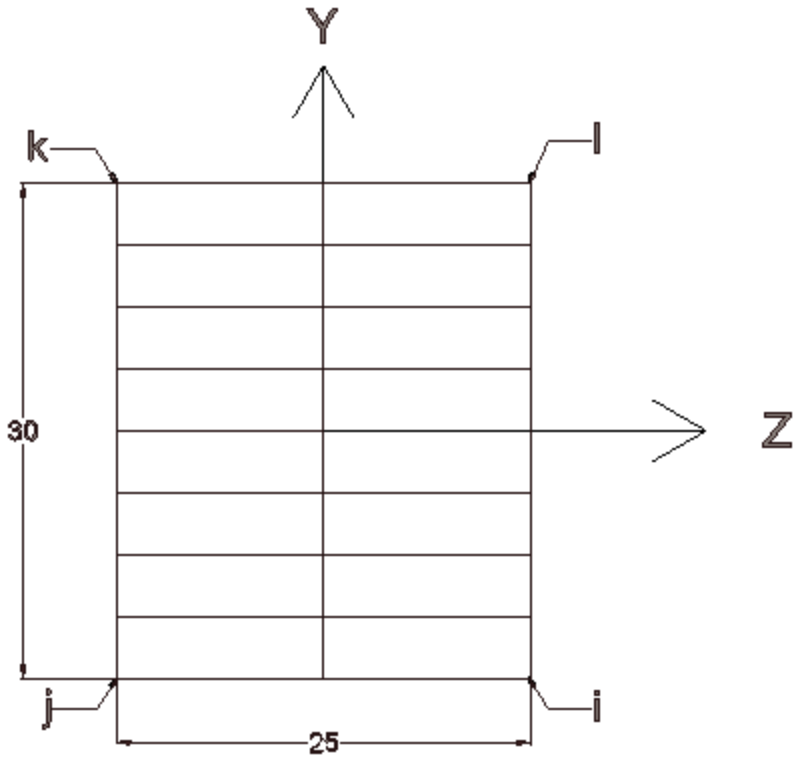
layer straight $matTag $numBars $areaBar $yStart $zStart $yEnd $zEnd

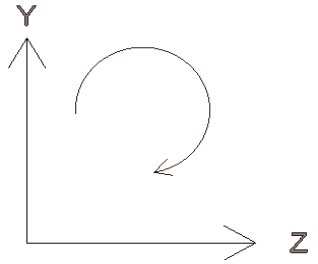


layer circ $matTag $numBar $areaBar $yCenter $zCenter $radius <$startAng $endAng>



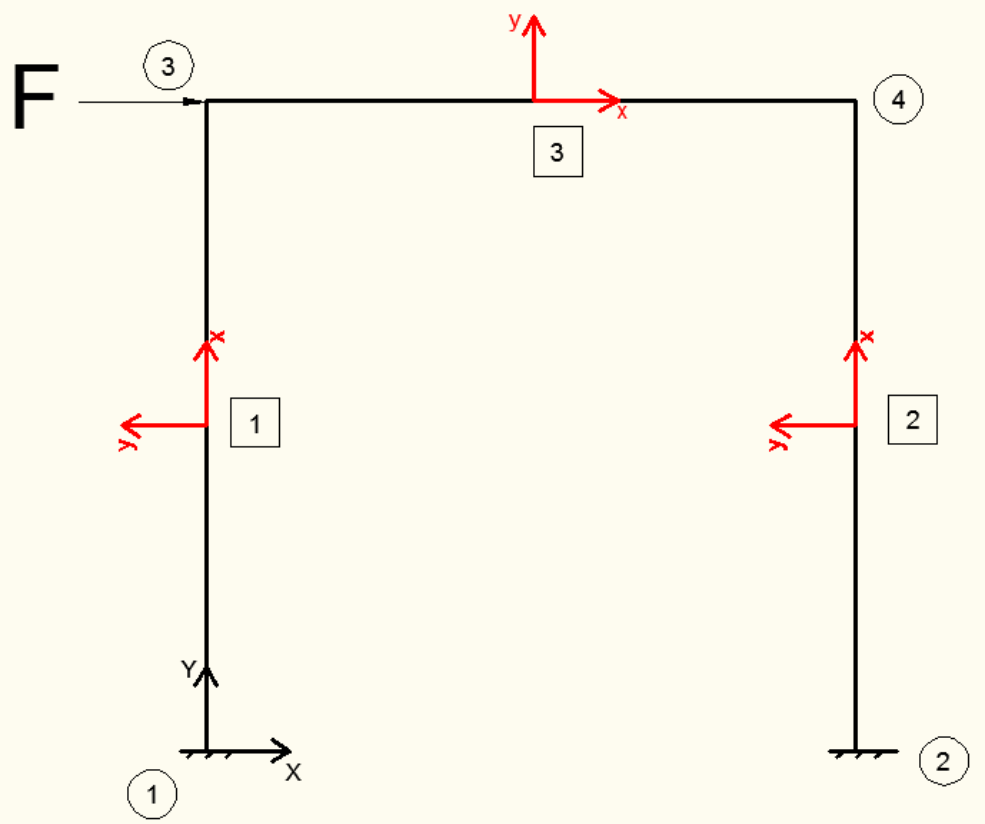
Fiber Section Example

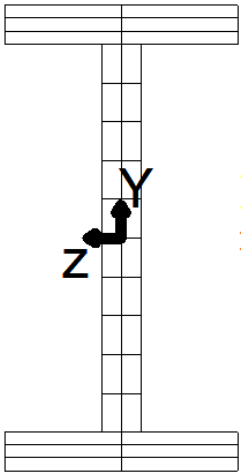





```
section Fiber 1 {
                          yI      zI      yJ      zJ      yK      zK      yL      zL
patch quad 1 2 8 -0.15    0.125  -0.15   -0.125   0.15  -0.125   0.15    0.125

}
```

Example 3-NonLinear Pushover





$bf = 10cm$

$d = 20cm$

$tf = 0.85cm$

$tw = 0.56cm$

Push the frame to 0.1m displacement of Node 4 in X dir.

Example 3-NonLinear Pushover

wipe

model basic -ndm 2 -ndf 3

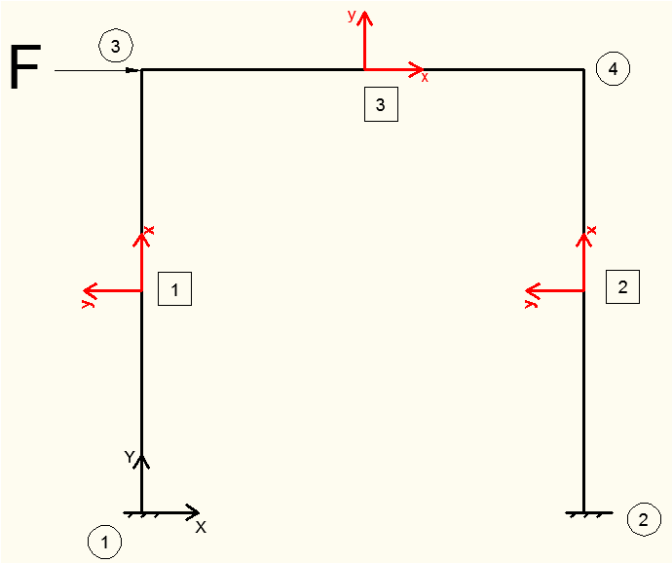
node 1 0. 0.
node 2 3. 0.
node 3 0. 3.
node 4 3. 3.

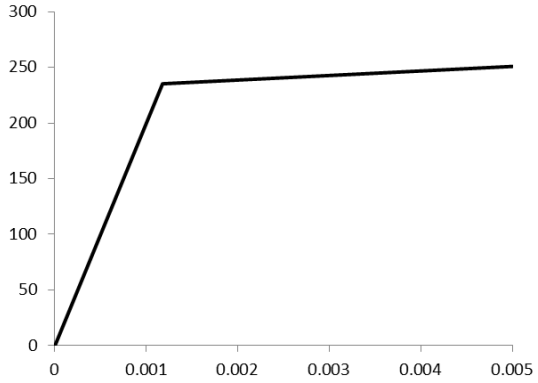
fix 1 1 1 1
fix 2 1 1 1

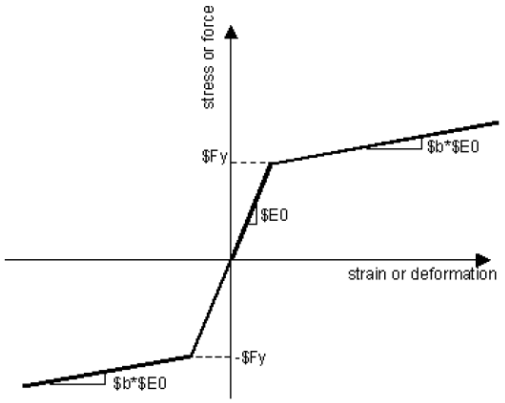
mass 3 2000. 0. 0.
mass 4 2000. 0. 0.

geomTransf Linear 1

uniaxialMaterial Steel01 1 2.354e8 2.e11 0.02

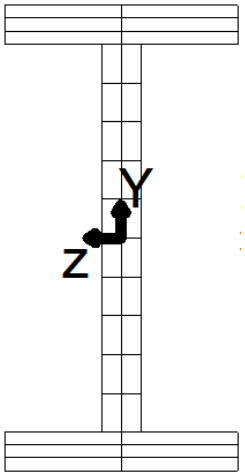






Example 3-NonLinear Pushover

```
wipe

model basic -ndm 2 -ndf 3

node 1 0. 0.
node 2 3. 0.
node 3 0. 3.
node 4 3. 3.

fix 1 1 1 1
fix 2 1 1 1

mass 3 2000. 0. 0.
mass 4 2000. 0. 0.

geomTransf Linear 1

uniaxialMaterial Steel01 1 2.354e8 2.e11 0.02
```



$bf = 10cm$

$d = 20cm$

$tf = 0.85cm$

$tw = 0.56cm$

```
section fiber 1 {
        patch quad  1 2 3    0.0915  0.05      0.0915  -0.05      0.1       -0.05     0.1       0.05
        patch quad  1 2 8   -0.0915  0.0028   -0.0915  -0.0028    0.0915    -0.0028   0.0915    0.0028
        patch quad  1 2 3     -0.1    0.05      -0.1    -0.05     -0.0915    -0.05    -0.0915    0.05
}
```

Example 3-NonLinear Pushover

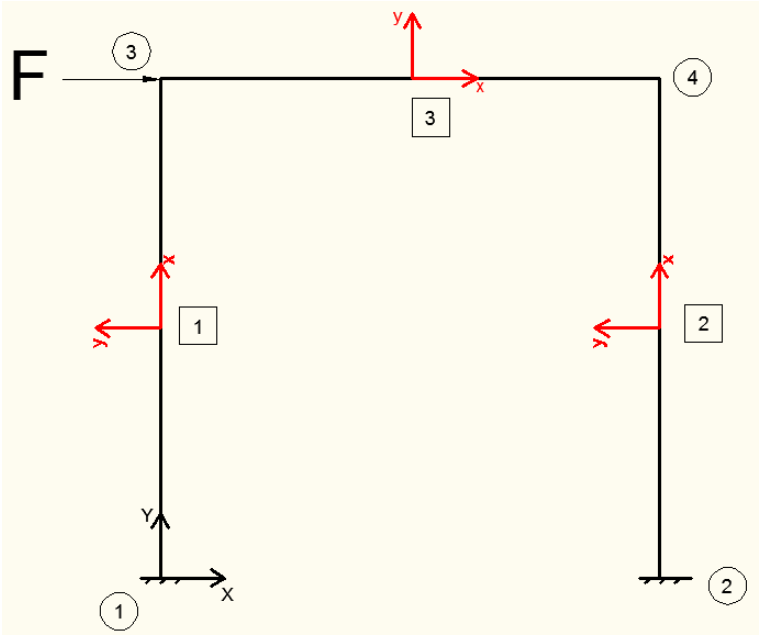
```
wipe

model basic -ndm 2 -ndf 3

node 1 0. 0.
node 2 3. 0.
node 3 0. 3.
node 4 3. 3.

fix 1 1 1 1
fix 2 1 1 1

mass 3 2000. 0. 0.
mass 4 2000. 0. 0.

geomTransf Linear 1

uniaxialMaterial Steel01 1 2.354e8 2.e11 0.02

section fiber 1 {
                patch quad  1 2 3  0.0915  0.05 0.0915 -0.05 0.1 -0.05 0.1 0.05
                patch quad  1 2 8   -0.0915  0.0028 -0.0915 -0.0028 0.0915 -0.0028 0.0915 0.0028
                patch quad  1 2 3    -0.1  0.05 -0.1 -0.05 -0.0915  -0.05 -0.0915 0.05
}
```

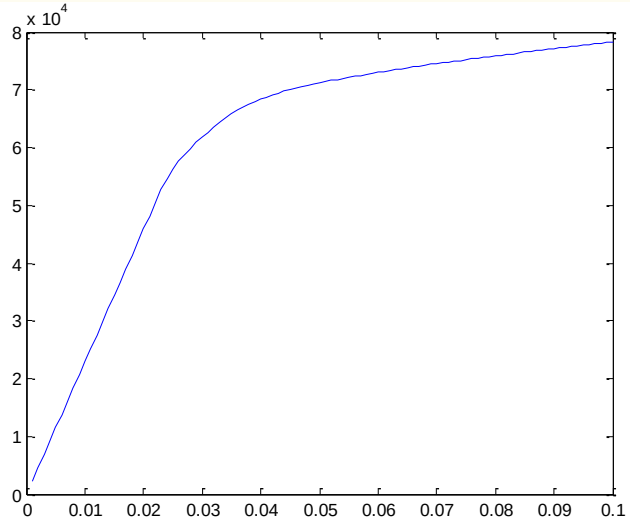
```
element nonlinearBeamColumn 1 1 3 10 1 1
element nonlinearBeamColumn 2 2 4 10 1 1
element nonlinearBeamColumn 3 3 4 10 1 1



pattern Plain 1 Linear {
load 3 10. 0. 0.
}

recorder Node -file node4disp.out -time -node 4 -dof 1 2 3 disp
recorder Node -file node1reac.out -time -node 1 -dof 1 2 3 reaction
recorder Node -file node2reac.out -time -node 2 -dof 1 2 3 reaction
```

Example 3 (Analysis)

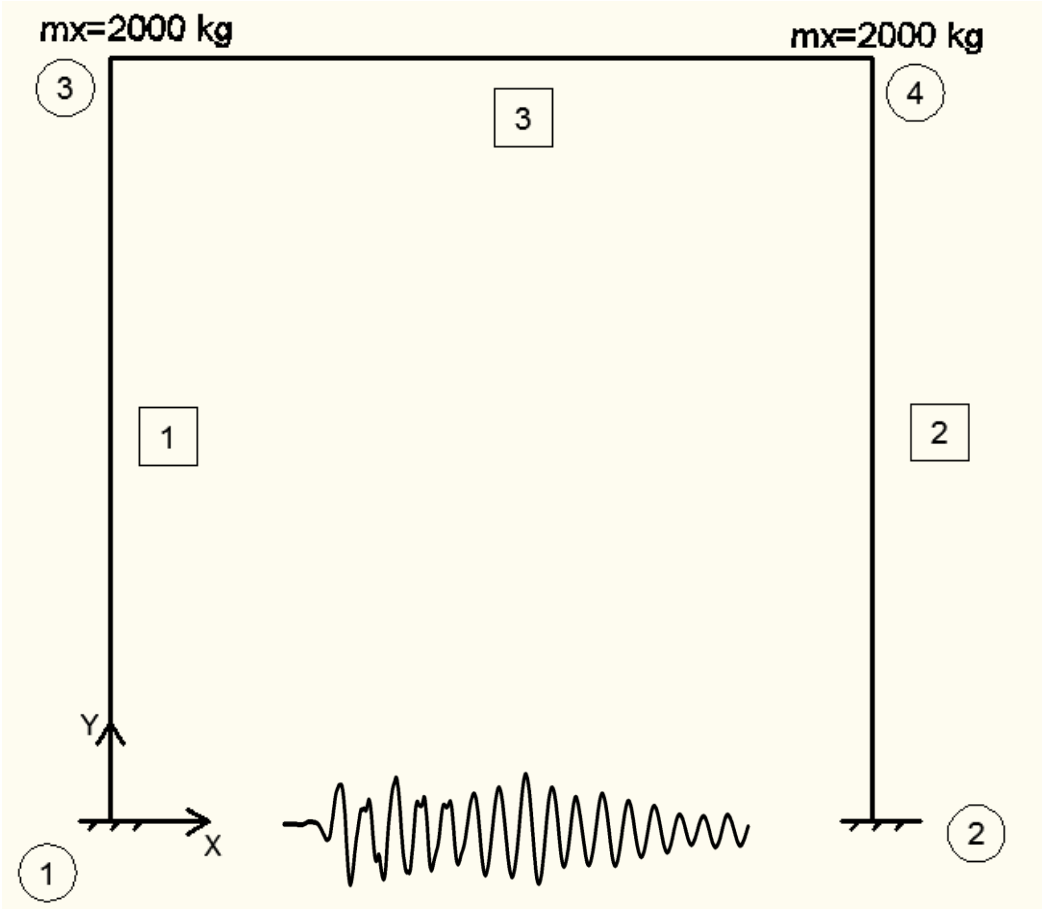
Static Nonlinear Analysis with Displacement Control

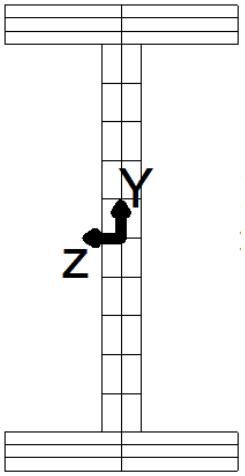
```
constraints Plain
numberer Plain
system BandGeneral
test NormDispIncr 1.e-8 6
algorithm ModifiedNewton
integrator DisplacementControl 4 1 0.001
analysis Static
analyze 100
loadConst -time 0.0
```





Example 4-1-NonLinear Earthquake-Without Damping





$bf = 10cm$

$d = 20cm$

$tf = 0.85cm$

$tw = 0.56cm$

Nonlinear Time History Analysis

Example 4-1-NonLinear Earthquake-Without Damping

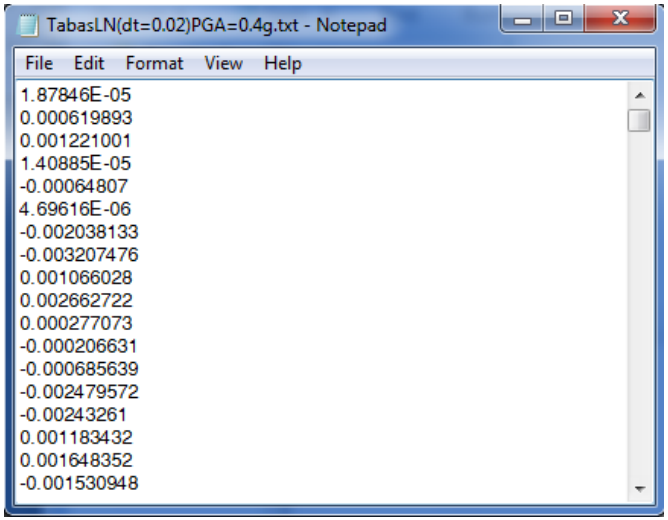
- **Uniform Excitation Pattern command**

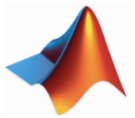
pattern UniformExcitation $patternTag $dir -accel (TimeSeriesType arguments) <-vel0 $ver0>

```
set accel "Series -dt 0.02 -filePath TabasLN(dt=0.02)PGA=0.4g.txt -factor [expr 9.81]"

pattern UniformExcitation 3 1 -accel $accel
```

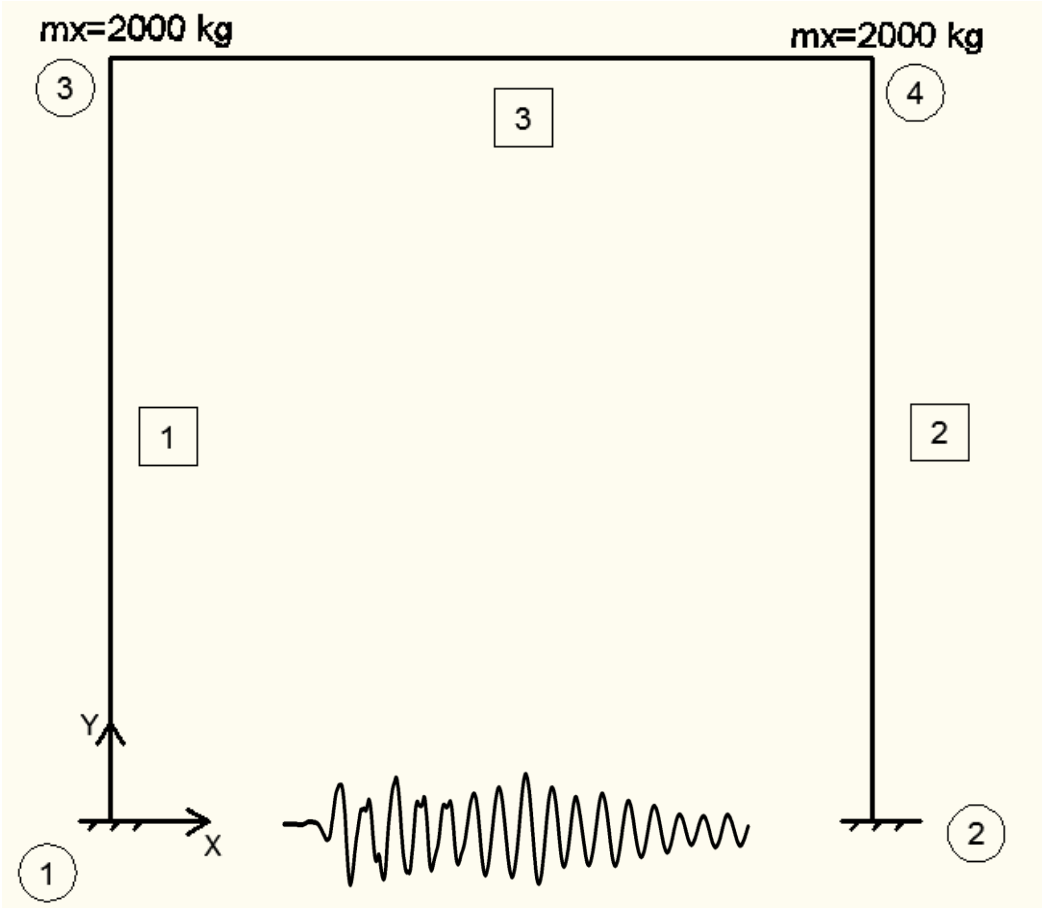
Time History Nonlinear Analysis

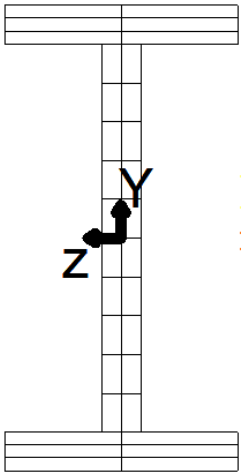
```
set dt 0.02

constraints Plain
numberer Plain
system BandGeneral
test NormDispIncr 1.0e-8 10
algorithm Newton
integrator Newmark 0.5 0.25
analysis Transient
analyze [expr int(32.82/$dt)] $dt
```





Example 4-2-NonLinear Earthquake-With Damping





$bf = 10cm$

$d = 20cm$

$tf = 0.85cm$

$tw = 0.56cm$

$\xi = 0.05$

Nonlinear Time History Analysis

Example 4-2-NonLinear Earthquake-With Damping

- **rayleigh command**

rayleigh $alphaM $betaK $betaKinit $betaKcomm

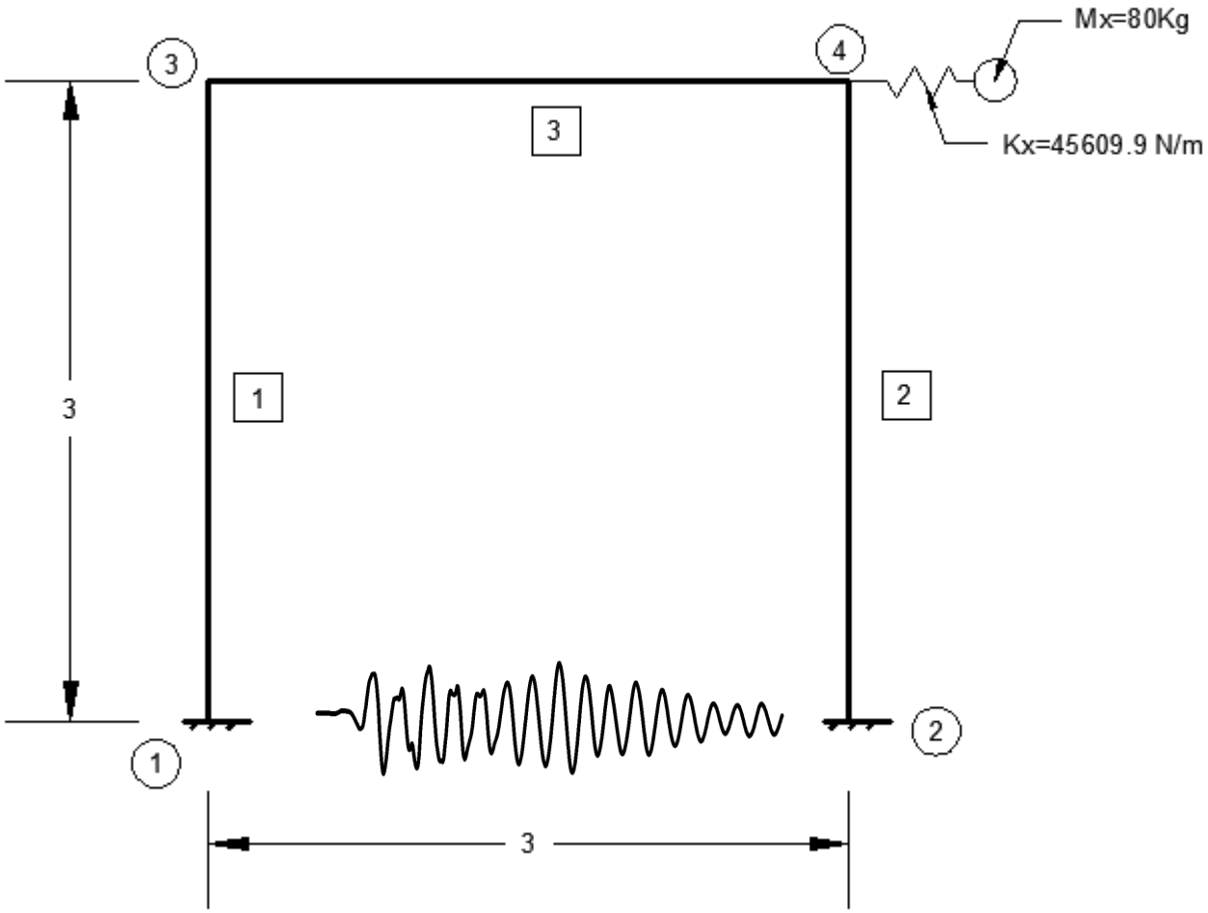
rayleigh 1.19 0 0 0.0021

$$\alpha = \frac{2\xi\omega_i\omega_j}{\omega_i + \omega_j}$$

$$\beta = \frac{2\xi}{\omega_i + \omega_j}$$

OpenSees

Example 4-4-NonLinear Earthquake-With Tuned Mass Damper



$M_{tmd} = 80\ Kg$

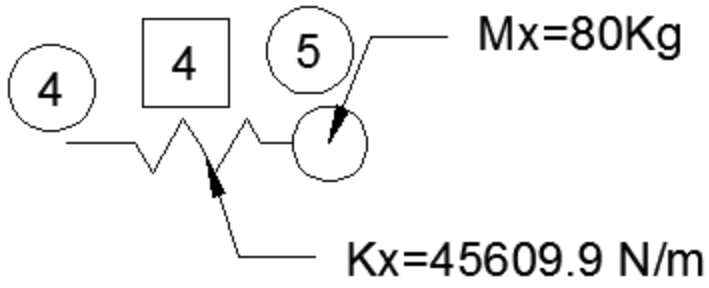
$K_{tmd} = 45609.9 \frac{N}{m}$

$C_{tmd} = 0$

$C_{structure} = 0$

Example 4-4-NonLinear Earthquake-With Tuned Mass Damper

How to model a simple Tuned Mass Damper:



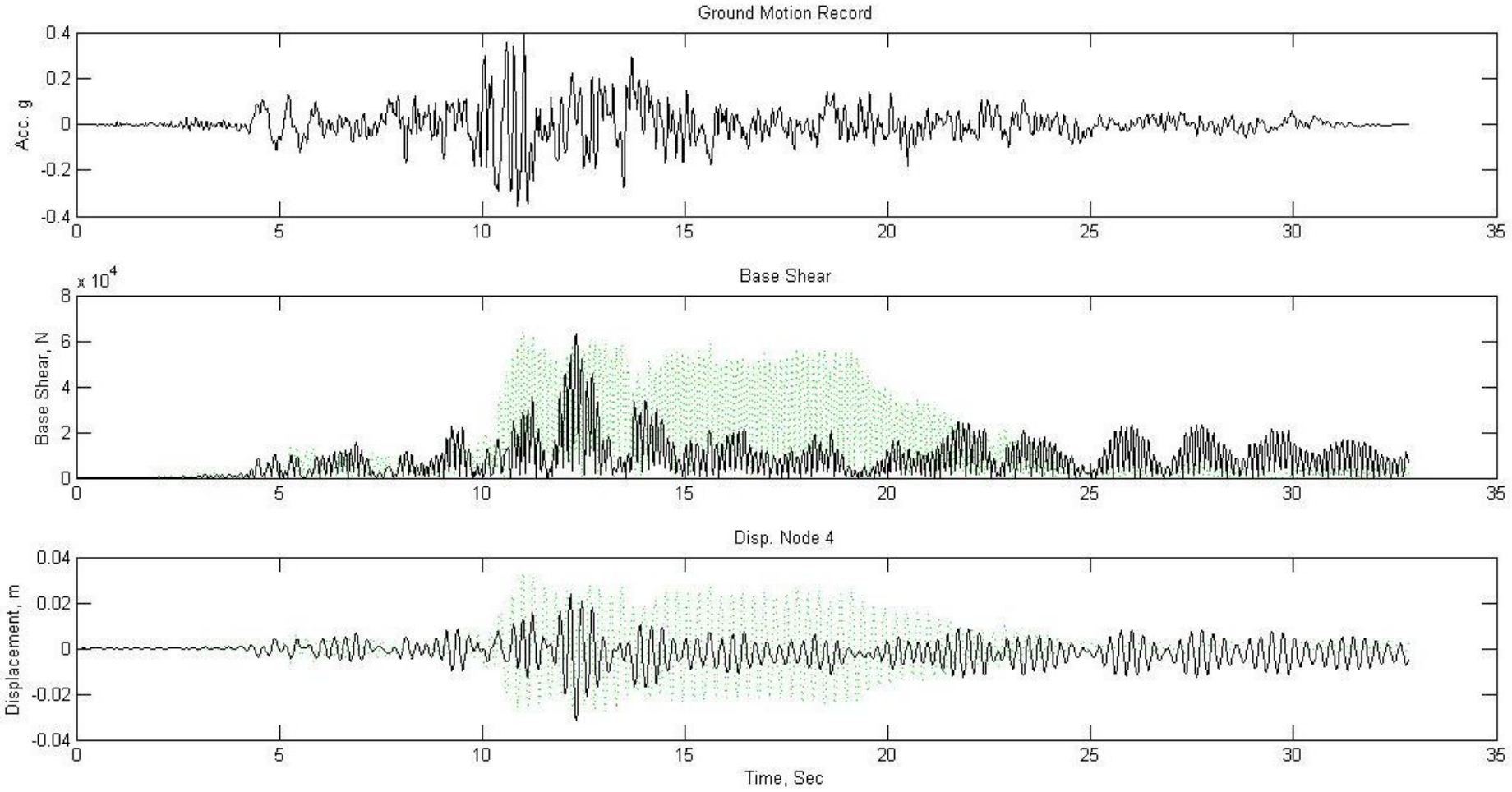
$$M_{tmd} = 80\ Kg$$

$$K_{tmd} = 45609.9\,\frac{N}{m}$$

$$C_{tmd} = 0$$

```
node 5 3. 3.

fix 5 0 1 1

mass 5  80. 0. 0.

uniaxialMaterial Elastic 2 45609.9
element zeroLength 4 4 5 -mat 2 -dir 1
```

Example 4-4-NonLinear Earthquake-With Tuned Mass Damper



Dotted Line: Uncontrolled

Bold Line: Controlled with TMD

Any Questions or Statements?

Earthquake Doesn’t Kill People, Buildings Do!

Thank You.

Nov. 2012